# COMBUSTION

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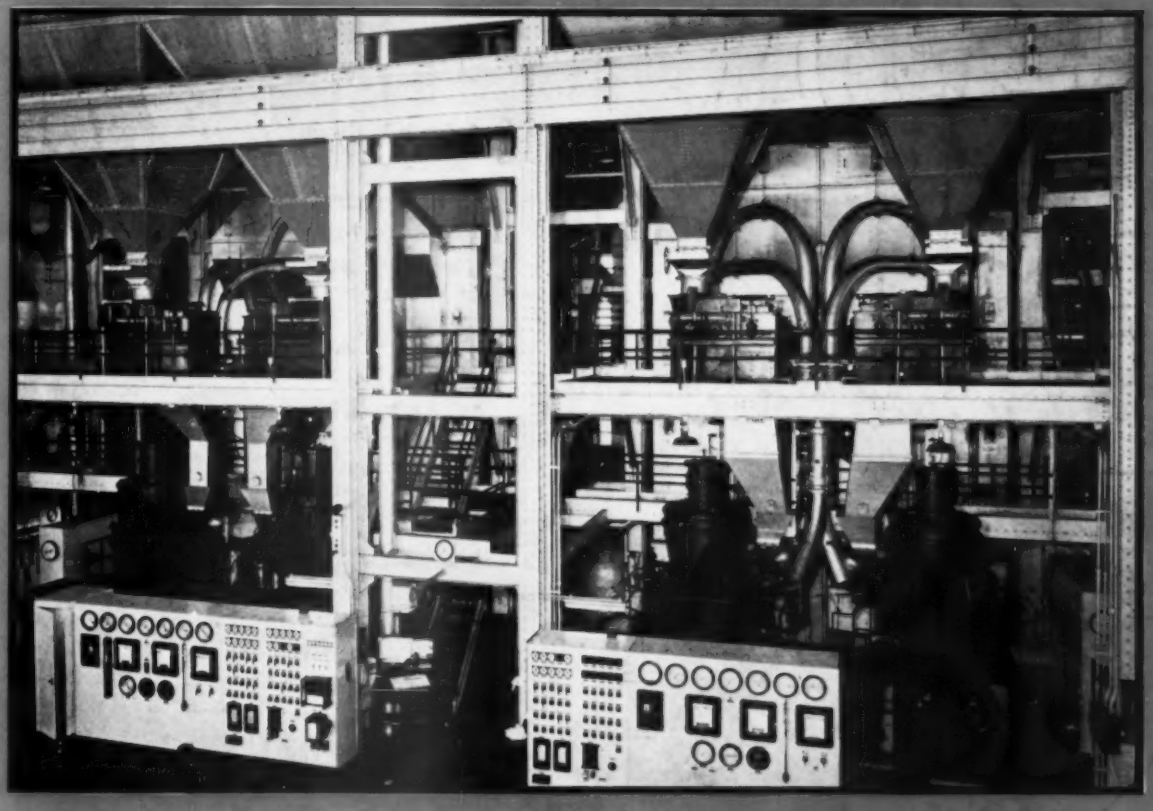

View of boiler room at the Hutsonville Station of the Central Illinois Public Service Company

**Estimating Temperatures Causing Damage to Plain Low-Carbon Steel Tubes**

**Influence of Inclination of Welds to Direction of Stress**

# Present day TRENDS in UTILITY Steam Practice

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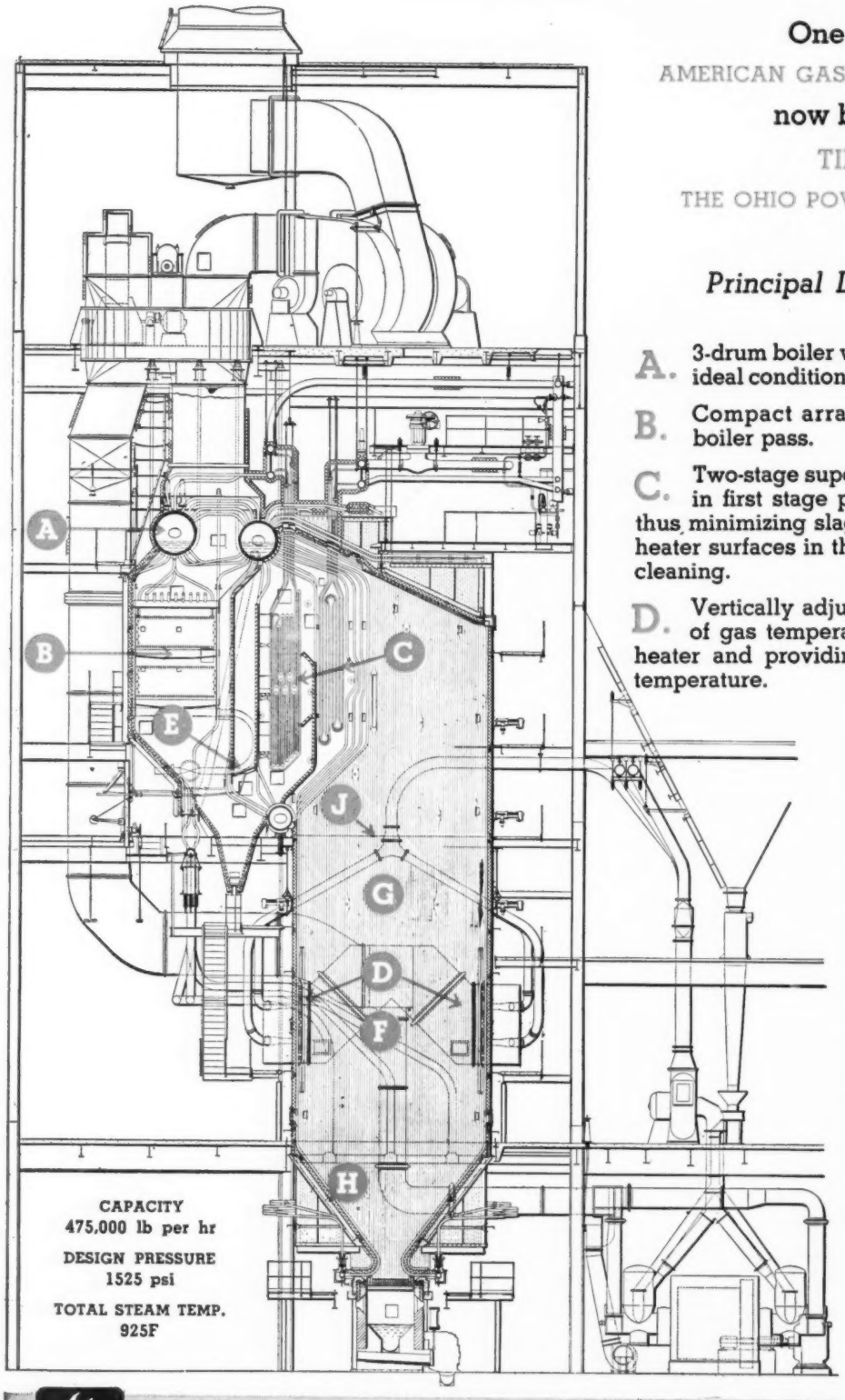


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**E.** Bypass damper which, in conjunction with desuperheater, provides final close control of superheat temperature.

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A-858

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# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIXTEEN NUMBER NINE


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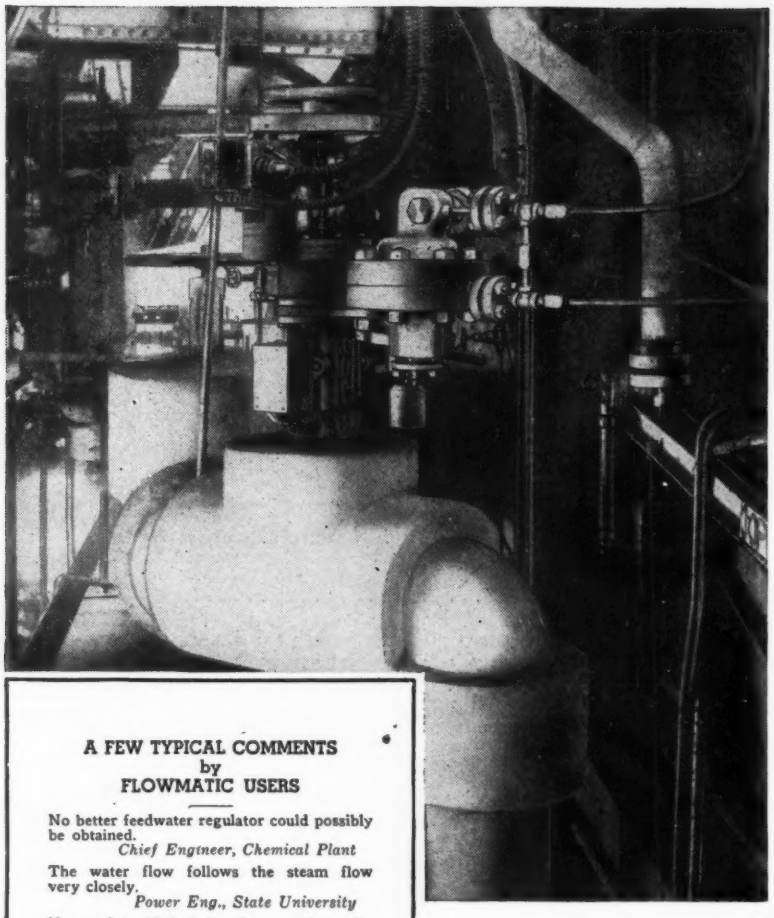

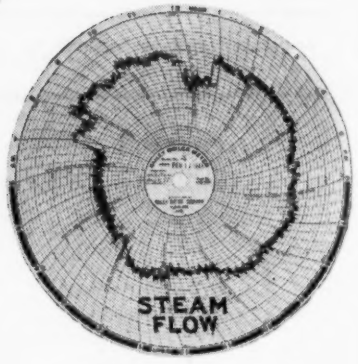


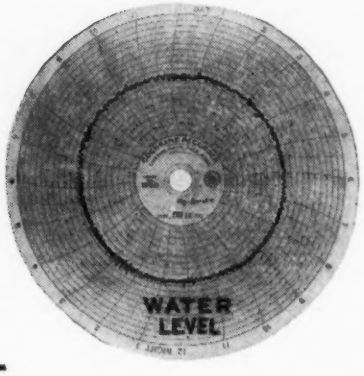


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# EDITORIAL

## Coal Supply Again Threatened

While the notice of a possible strike of bituminous coal miners on or after April first, which John L. Lewis recently filed with the Secretary of Labor, was a formality to comply with the Smith-Connally Act, its contents gave a clue to Mr. Lewis' attitude and to the miners' demands, some of which have subsequently been reported in the press. Although, under the existing law, a strike vote by the union membership will be necessary, the result would be a foregone conclusion.

It had been hinted that Mr. Ickes might have been holding an ace up his sleeve in that he continued to control certain mines under previous government seizure, and thus be in a position to invoke severe penalties under the Smith-Connally Act for striking against the Government; but Mr. Lewis shrewdly exempted these cases, and on February 24 seventy-two of these mines in West Virginia, Pennsylvania and Kentucky were returned to private possession.

Should the negotiations now going on between the coal operators and the miners' committee fail, as seems probable in view of some of the demands, there is likely to be a repetition of the Government's 1941 and 1943 actions in taking over operation of the mines by Presidential order. It will be recalled that in the latter year an estimated forty million tons of coal output was lost because of work stoppages, and that the final settlement acceded to most of Mr. Lewis's demands, with the increases reflected in the price of coal to the consumer.

However, the lost coal production was not so serious in 1943 as it had been possible to build up stockpiles to provide a substantial reserve. But at present the situation is quite different. Not only did the severe weather of last January and part of February result in lowered output, because of disrupted transportation, but these conditions led to further depletions of stockpiles, in many localities to a dangerous degree. Moreover, current schedules for increased war production and shipments abroad are expected to result in a bituminous coal demand for 1945 exceeding estimated output by about forty million tons, provided there are no interruptions in supply. This deficit is just about offset by stocks now in hand, but these stocks are not distributed geographically nor by industries such as to prevent serious shortages. This is particularly true as concerns the steel mills and certain other vital war industries. Of course, an early termination of the war with Germany would tend to cut back the demand to some extent, but this would not be reflected immediately and the war in the Pacific would continue with heavy requirements.

Although further increases in coal prices will not be well received by consumers, it is believed they are not adverse to such adjustments as would make the miners' wages comparable with those of workers in other basic industries, if such discrepancy is shown to exist, provided this can be brought about within the scope of the "little steel" formula which the Government has insisted must be maintained. While some of the announced demands might be construed as not in technical violation of this formula, they certainly run counter to its spirit. Moreover, it is doubtful if public opinion will countenance the proposed levy of ten cents per ton of coal mined in order to build up a fund for Mr. Lewis's union despite the uses to which he contends it would be put.

Above all, it is imperative that there be no interruption in coal supply. The public is becoming fed up with these cyclic disturbances in the coal industry and would welcome the establishment of some policy by which the conditions could be stabilized for a longer period than two years, which has been the practice under the existing contract procedure.

## Returning Servicemen

With fighting at its height on all fronts and the pending national service legislation occupying the headlines, reemployment of veterans may seem distant. Yet thousands are being returned home with various degrees of disability and some are being discharged to civilian life for other reasons.

Industry is not only in general agreement with the G. I. Bill of Rights, but in many cases is preparing to go further than the requirements therein outlined. Nevertheless, there are many angles to the situation that require careful planning and thoughtful handling if embarrassing situations are to be avoided and all parties concerned are to be fully satisfied.

Conscious of this fact, many of the larger companies are now giving serious attention to plans for the reception and placement of returning employees—not only as to immediate cases but as to the future when demobilization will involve large numbers over an extended period. The problem is complicated by difficulty in forecasting business conditions in certain lines during both the conversion and post-war periods.

Several of the large insurance companies, as well as the U. S. Chamber of Commerce, have initiated studies of the situation and conducted surveys of numerous company plans already made. These findings have been issued in pamphlets which should be most helpful to those still engaged in making plans, as well as those who have not yet given concrete thought to the problem.

# Estimating Temperatures Causing Damage to Plain Low-Carbon Steel Tubes

BY RICHARD C. COREY

Research and Development Dept.,
Combustion Engineering Company

**The author reviews the principal causes of tube failures and discusses how the probable temperatures to which they have been subjected can be estimated by means of metallographic examination of microstructure changes. The basis of such studies is explained and limitations pointed out.**

THE primary causes of failure of furnace, boiler or superheater tubes are; (*a*) overheating, resulting from impedance to the transfer of heat from the metal to the water or the steam by scale or deposits on the water or steam side of the tubes, and (*b*) reduction of the wall thickness of the metal by pitting or general corrosion. Failure in either case occurs when the ultimate strength of the metal, at the temperature existing at the point of failure, is exceeded. Defects in the steel such as slag-stringers, tool marks and laps which result when folds formed in the metal during fabrication are not hot-worked sufficiently to weld them together, may lower the ultimate strength of the metal locally or impair the resistance to alternating stresses. Although such defects may facilitate failure and affect somewhat the location of the failure, rarely are they extensive enough to be the primary cause.

In cases where corrosion has reduced the wall thickness of a tube appreciably, under conditions where overheating is unlikely, the reason for failure is obvious. On the other hand, when there is no evidence that corrosion has been active, and failure is accompanied by bulging of the metal, and cracks with edges of reduced cross-section, overheating of the metal is indicated.

In diagnosing the cause of swelling or rupture of a tube, an estimate of the temperature which caused deformation of the metal is a valuable supplement to other necessary data, such as the composition of any scale or deposits found at the site of the failure and the feed-water treatment and operating history of the unit.

Efforts have been made, without success, to determine this temperature by measuring the reduction in thickness of the metal at the edges of a crack and the amount of elongation that took place. Theoretically, this would appear to be a rational method, for if one had complete data on reduction of thickness and elongation for the same metal at various temperatures, correlation with the changes in the defective tube might be possible. Difficulties lie, however, in the interpretation of the measurements. For example, if these properties of the normal steel are measured with a tensile testing machine, using the standard technique, the test specimens are of specified length and thickness and the stress is applied at a certain rate along a single axis of the specimen. In a boiler tube the stresses causing deformation are transverse, longitudinal and radial and are more or less constant over an unknown period of time. Consequently, the possibilities of this method are remote. Likewise, measurements of the hardness of the metal in the defective area are subject to a number of variables which do not permit correlation with the maximum temperature attained by the metal.

It is possible under certain conditions, however, to establish by means of a metallographic examination of the tube metal at, and adjacent to, the defective area, the probable temperature *range* in which the metal was heated, or a certain minimum temperature that was exceeded. For fundamental metallurgical reasons, which will be discussed, the limitation to this method is that the exact temperature cannot be determined. This is not a serious drawback, however, as in most cases it is sufficient to know only that a certain temperature was exceeded.

### *Rapid Cooling Provides Indicative Microstructure*

The basis for this method of examination lies in the fact that if steel is quenched from above about 1350 F, the rate of cooling being at or higher than a given critical rate of cooling, microstructures are found in polished and etched specimens which can be related to certain temperature limits to which the metal was heated. If, however, the cooling rate from temperatures at which microstructural changes are known to occur in quenched steel is too slow, it is probable that the normal structure will be found. Therefore, when an overheated boiler tube bursts, the steam and water issuing from the crack quenches the metal, fortuitously in most cases at a rate higher than the critical cooling rate, a metallographic examination of the metal at and adjacent to the crack makes it possible to estimate the temperature, within limits, of the metal prior to failure. Occasionally, however, the cracked metal may be reheated by hot refractory to a sufficiently high temperature so that if slow cooling takes place, the final microstructure may not be distinguishable from that of the normal metal.

For an understanding of the principles involved, it is desirable to discuss briefly the physical metallurgy of plain low-carbon steel; physical metallurgy being that branch of metallurgy dealing with the structure and properties of metals and alloys, as distinguished from manufacturing and fabricating technology.

### *Transformations in Pure Iron*

Pure iron, free of impurities, carbon and other alloying elements, undergoes changes in chemical and physical properties at various fixed temperatures. These changes account for the varied and unique physical properties that can be secured from steel by such heat-treating operations as quenching, drawing, normalizing and austempering.

Pure iron at room temperature is designated as *alpha* iron. It is strongly magnetic and has a crystal structure that is known as body-centered cubic (B.C.C.), meaning that the smallest geometric arrangement of the iron atoms that can be repeated indefinitely in three dimensions to produce a crystal of iron, is a cube with an iron atom at each corner and one at the center of the cube. This is the *unit cell* of iron. If a small block of pure iron, with a thermocouple embedded in the middle of the mass, is heated at a slow, constant rate it will be found that at a temperature of 1418 F the temperature of the iron remains constant for a short period of time, indicating an isothermal absorption of heat. At this temperature the iron becomes non-magnetic, the crystal structure remaining B.C.C.

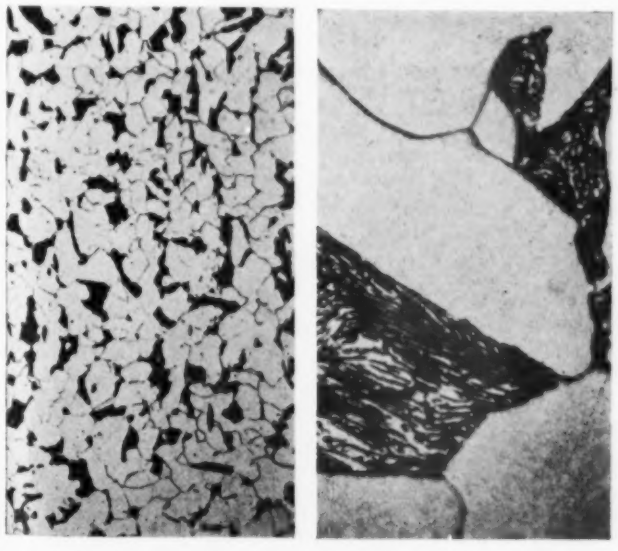


**Fig. 1—Microstructure of normal 0.15 per cent carbon boiler tubing**
**Left: General structure at 100 magnifications**
**Right: Details in pearlite at 1000 magnifications**

As heating is continued, at a temperature of 1670 F, another isothermal absorption of heat occurs as the result of a rearrangement of the atoms in the iron so that the structure of the unit cell becomes face-centered cubic (F.C.C.); that is, cubes with an atom in the center of each face. The iron still is non-magnetic and retains the F.C.C. structure up to 2552 F, and is known as *gamma* iron in the interval between 1670 and 2552 F. Between 2552 F and the melting point, 2795 F, the iron again becomes B.C.C. and is known as *delta* iron. These transformations may be summarized as follows:

| Form of Iron | Crystal Structure | Magnetic Properties | Range of Stability, deg F |
|---|---|---|---|
| Alpha ($\alpha$) | B.C.C. | Magnetic | Room temp. to 1670 |
| Gamma ($\gamma$) | F.C.C. | Non-magnetic | 1670 to 2552 |
| Delta ($\delta$) | B.C.C. | Non-magnetic | 2552 to 2795 |

The principal phases that occur in plain carbon steels as the result of different heat treatments are as follows:

(*a*) *Ferrite* is *alpha* iron containing carbon in solid solution. The solubility of carbon is very small, being a

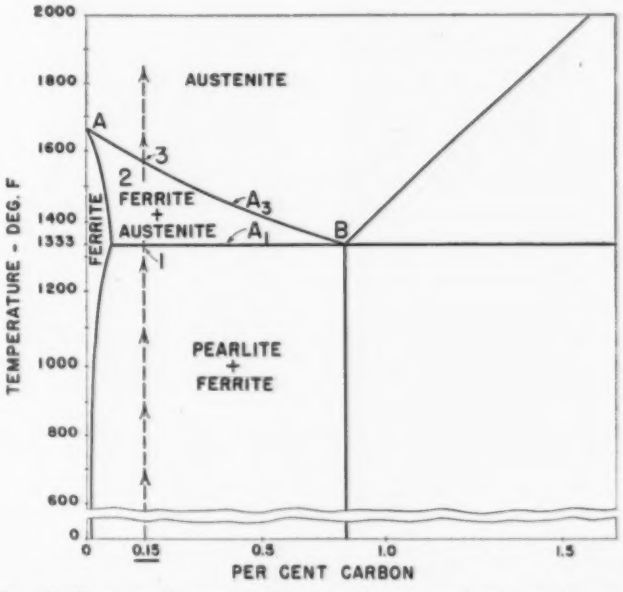



**Fig. 2—Iron-carbon equilibrium diagram showing changes which occur when 0.15 per cent carbon-steel is heated**

maximum of 0.035 per cent at 1333 F, and only 0.01 per cent at room temperature.

(*b*) *Austenite* is *gamma* iron containing carbon in solid solution. The solubility is much greater than in alpha iron, being a maximum of 1.7 per cent at 2066 F.

(*c*) *Cementite* is a compound of iron and carbon represented by the formula $Fe_3C$. It is very hard and brittle and rapidly decomposes above 2000 F to iron and graphite.

(*d*) *Pearlite* is defined as a *eutectoid* mixture of ferrite and cementite, these phases being distributed as alternate lamellae. All slowly cooled steels containing less than 0.83 per cent carbon will consist of pearlite and ferrite, the relative proportions of these two phases depending upon the carbon content of the steel.

(*e*) *Martensite* is the structure obtained when steel containing austenite is quenched, the rate of cooling being at, or exceeding, a critical rate of cooling. It is characterized by a needle-like, or acicular, pattern and constitutes the hardest constituent in steel.

### *Low-Carbon Seamless Steel Tubing*

The material to which subsequent discussion will refer is plain low-carbon seamless steel tubing for high-pressure service, with the following A.S.M.E. specification for chemical composition:

| | |
|---|---|
| Carbon | 0.08–0.18 % |
| Manganese | 0.30–0.60 % |
| Sulfur, max | 0.045% |
| Silicon, max | 0.25% |
| Phosphorous, max | 0.04% |

The specifications require that cold-drawn tubing be fully annealed, the annealing of hot-finished tubing being at the option of the purchaser.

The microstructure of a section of typical, normal boiler tubing containing 0.15 per cent carbon is shown in Fig. 1. To resolve the structure, the specimen was carefully polished, and etched lightly with a 3 per cent solution of nitric acid in alcohol, which is the standard metallographic practice for this type of material. The lower magnification, at the left, shows distinct light and dark areas, the light areas being known as *primary ferrite*, and the dark areas as *pearlite*. The higher magnification, at the right, resolves the pearlite into alternate light and dark bands of ferrite and cementite, as described above, and for this reason it is termed *lamellar* pearlite.

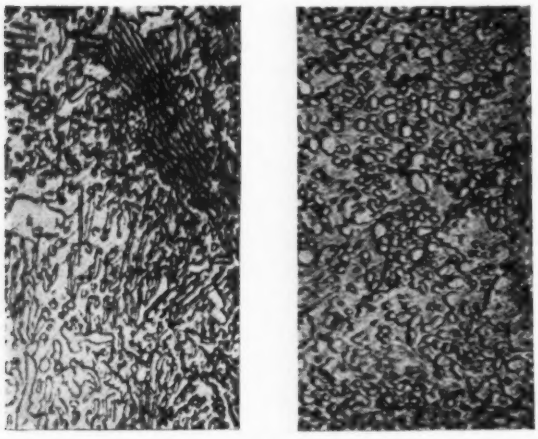


**Fig. 3—Partial (left) and complete spheroidization (right) of pearlitic cementite in 0.15 per cent carbon-steel (500 magnifications)**

### *Iron-Carbon Equilibrium Diagram Shows Changes With Heating*

The phases, or individual microconstituents, in steel which has been slowly heated or slowly cooled to various temperatures may be represented by Fig. 2, which is the iron-carbon equilibrium diagram. It should be emphasized that the phase boundaries of this diagram were established from experiments conducted under equilibrium conditions and that rapid heating or cooling of the steel shifts the boundaries markedly. For the purpose of this discussion, however, it may be reasonably assumed in most cases that the rise in temperature of a tube under operating conditions is sufficiently slow, so that the information available from the iron-carbon diagram applies.

### *Temperature Range up to 1333 F*

Considering only fully annealed 0.15 per cent carbon steel, the diagram shows that as the metal is heated up to *1*, corresponding to a temperature of 1333 F, the structure will remain as shown in Fig. 1, namely, grains of ferrite and pearlite. This temperature is known as the *lower critical* of steel and is designated as the $A_1$ point. As implied above, the $A_1$ point for a given steel, other things being equal, will shift with the rate of heating. Prolonged heating of this steel at temperatures around $A_1$ will cause coalescence of the cementite lamellae in the pearlite into a globular form known as *spheroidized* cementite. Partial and complete spheroidization are shown in Fig. 3. The rate at which this change occurs is a function of time and temperature, being very rapid around $A_1$ and extremely slow around 1000 F. Numerous factors, too detailed to discuss here, affect the rate of spheroidization of plain carbon steels. Therefore, it would be indeed difficult to establish the temperature to which a tube had been subjected from the extent of spheroidization of cementite.

### *Temperature Range From 1333 F to 1570 F*

As the temperature of the steel is increased slowly beyond $A_1$ into the region *2* shown in the diagram, the pearlite grains begin to transform to austenite which absorbs some of the surrounding ferrite grains by a process of diffusion.

At point *3*, corresponding to a temperature of about 1570 F for 0.15 per cent carbon steel, the metal becomes entirely austenite. At intermediate temperatures between the $A_1$ and $A_3$ points, quenched specimens will show the original lamellar pearlite to have an acicular structure characteristic of martensite and the relative proportions of ferrite and martensitic grains will depend upon the temperature in this range that was reached and the time at this temperature before quenching occurred. The photomicrograph in Fig. 4 is that of a section from the ruptured area of a high-pressure boiler tube. The temperature of the metal before quenching occurred was between 1350 and 1570 F, possibly about 1450 F. It is to be noted that the original pearlite areas have assumed a somewhat feathery contour and the structure no longer is lamellar.

**Fig. 4—Photomicrograph of polished and etched section of boiler tube that has been heated between 1350 and 1570 F and quenched (100 magnifications)**
**Courtesy of L. E. Hankison, West Penn Power Co.**

### *Temperatures Above 1570 F*

Quenching from above the $A_3$ point results in a completely martensitic structure as shown in Fig. 5. If the temperature reached by the metal prior to failure greatly exceeds the $A_3$ point it is difficult to make an estimate of the temperature. At temperatures in excess of about 1650 F numerous changes may occur in time in plain carbon steel which cannot be related to any definite temperature inasmuch as the time the metal is at these temperatures is an important factor. Suffice to mention, however, that evidence of grain-growth, intercrystalline cracks filled with iron oxides, and extensive decarburization indicates that the temperature has far exceeded the upper critical. The photomicrograph in Fig. 6 shows the edge of a failure in which the metal temperature probably exceeded 1800 F and cooled relatively slowly. This is evidenced by severe internal oxidation ("burning") with the formation of Fe-FeO eutectic, coarsened grain boundaries, and a Widmanstaetten structure in the outer grains, characterized by long needle-like plates.

### *Bulged Tubes*

An estimate of the temperature causing bulging of a tube is practically impossible as such deformation of the metal not only is dependent upon time and temperature, but microstructural changes as the result of quenching, as previously mentioned, do not occur unless the metal cracks. Some investigators have relied upon the extent of spheroidization of the cementite in the deformed area as an indicator of the probable temperature causing bulging, but due to the indeterminate variables which are involved in this process, such estimates are of little or no value.

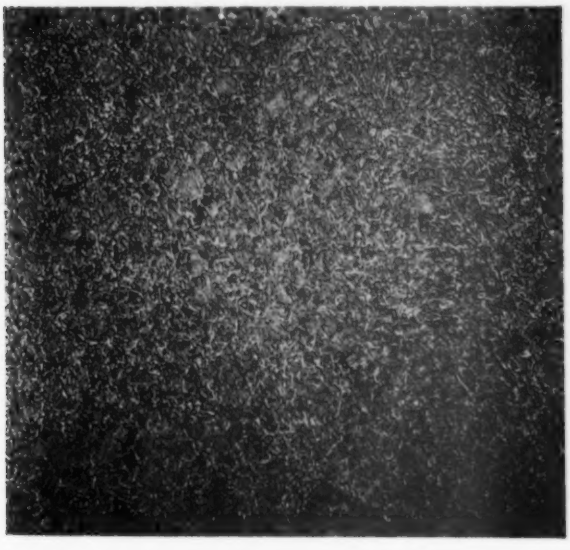


**Fig. 5—Martensitic structure in a boiler tube resulting from quenching occurring above 1570 F (100 magnifications)**
**Courtesy of L. E. Hankison, West Penn Power Co.**

### *Conclusions*

The following conclusions may be made from the foregoing discussion:

1. Measurements of the reduction of thickness, elongation, hardness and tensile strength in the deformed area of ruptured boiler and superheater tubes cannot be related reliably to the temperature that caused failure to the metal.

2. Fairly reliable estimates of temperature may be made by a metallographic examination in cases where the metal has been heated to between 1350 F and 1600 F and rapidly quenched by water and steam issuing from a crack. If reheating occurs after failure of the metal, followed by slow cooling, the resulting microstructure probably will not differ appreciably from the original microstructure. Hence estimates of the maximum temperature to which the metal has been subjected is not possible under such conditions.

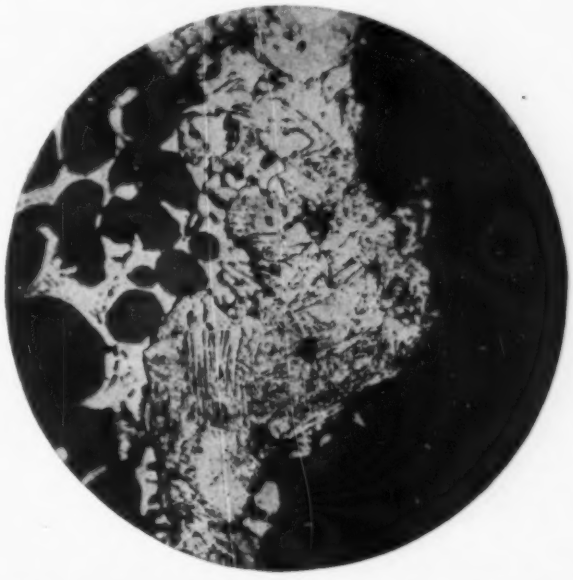


**Fig. 6—Severely overheated area in a ruptured, high-pressure boiler tube (500 magnifications)**

3. The microstructural changes occurring below 1350 F and above 1600 F in plain 0.15 per cent carbon steel, such as grain-growth, spheroidization of the cementite, decarburization, intergranular oxidation, the presence of non-metallic eutectics and Widmanstaetten structure are not criteria of the temperatures causing failure of the metal.

There have been instances where an examination of the metal structure of a failed tube had led to the conclusion that the tube had been overheated in service; but where subsequent examination of the metal in unused tubes of the same stock, or parts of the tube not exposed to high temperature, had shown the same type of structure. This clearly indicated that the condition was brought about during the process of manufacture. In other words, it is always well to take into consideration the condition and the history of the stock before attempting to arrive at definite conclusions as to the cause of a tube failure.

It may be pointed out further that, in a case where a tube is observed to have been stretched in the absence of corrosion, the indications are clear that its tensile strength has been reduced by temperature to a point where the stress, due to internal pressure plus that due to temperature, has exceeded the tensile strength of the metal.

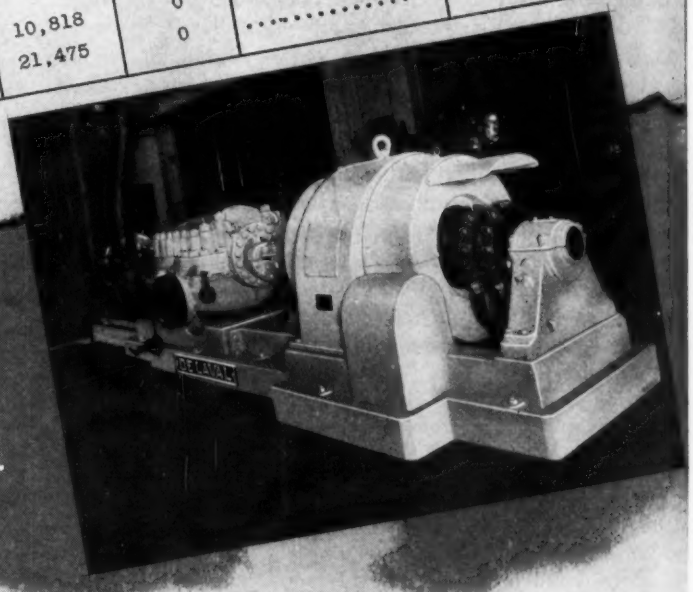
# Look at the Record!

SERVICE RECORD—As of September 1, 1944

DE LAVAL PUMPS at _____

| No. | Discharge Pressure psig | Suction Temp. °F. | Placed in Service | Total Service Hours | Outages Due to Pump | Cause of Outages | Approx. % Increase in Pump Power |
|---|---|---|---|---|---|---|---|
| 14 | 1186 | 260° | 12- 2-38 | 40,383 | 2 | Replace ball locating bearing and shaft sleeves | Negligible |
| | | | | | 1 | Replace shaft sleeves | Negligible |
| | | | 10-11-40 | 28,839 | | ..... | Negligible |
| 15 | 1186 | 260° | | | 0 | ..... | 5% |
| | | | 8- 4-39 | 10,818 | | | |
| 21 | 1186 | 350° | 1- 2-42 | 21,475 | 0 | ..... | |
| 16 | 1186 | 260° | | | | | |

Capacity (all units).....1455 g.p.m.



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# Influence of Inclination of Welds to Direction of Stress*

**When computing welds it is common practice to assume a higher joint efficiency along the weld than perpendicular to it. Consequently, inclination of the weld in the direction of stress should bring about an increase in load, and this assumption has led to some firms adopting spiral welds in pipe lines and drum construction. Tests on tensile bars and model drums, however, have now shown that it is only with relatively low joint efficiencies and very small angles between the axis of the weld and the principal direction of stress that any real increase in load can be achieved.**

IF a weld at first arranged perpendicular to the tensile stress is increasingly inclined until it runs in the direction of tension, the stress component acting at right-angles to it will become smaller and smaller and finally vanish altogether. Hence, assuming material of the same gage, increasing inclination of the weld should result, theoretically, in a gain in the permissible load on the welded joint, or, for the same load, plates of smaller gage could be employed. This viewpoint has led to lower factors of safety or greater stresses perpendicular to the weld being allowed for drums or pipe lines with spiral or helicoidal welds. For spiral welds inclined 45 deg, the increase is stated to be 20 per cent and is claimed to represent an important economic advantage in drum construction as well as in many general engineering applications. Notwithstanding the fact that the process has been widely applied industrially, few details are to be found in technical literature. Of particular interest is the relation between the increase in load or reduction in plate thickness and the joint efficiency. Apparently the increase is greater the lower the efficiency of the weld and the greater its inclination. If the welded joint is of the same quality as the parent material, i.e., the joint efficiency = 1, no advantage whatsoever accrues from inclining the weld.

The aim of the investigations here described was to determine experimentally, whether, under conditions of static tensile stress and with different joint efficiencies, any advantage is actually to be derived from inclining welds, and if so in what way and to what extent.

### *Testing Methods*

Tensile tests were carried out on flat bars and internal pressure tests on small model boiler drums. In this way, one-dimensional stress, such as is encountered in long pipe lines and rotating drums, as well as three-dimensional stresses, met with in boiler drums and pressure vessels, were taken into consideration. The test specimens employed are illustrated in Fig. 1.

Appropriate reduction of cross-section of material by providing a groove on either side was selected as a substitute for the weld. In this way the modulus of elasticity is not impaired and nevertheless a notch effect is obtained which fundamentally corresponds to that of welding defects. It was possible to inyestigate joint efficiencies of 1, 0.8 and 0.4 by employing specimens reduced in section by 0, 20 and 60 per cent, respectively. The following series of tests were carried out:

(*a*) Comparison of welding defects and specimens grooved to give a reduced section.
(*b*) Tests with unwelded and welded flat bars, the weld unmachined and also machined level with plate.
(*c*) Tests with flat bars and pressure vessels of non-reduced section and reduced 20 per cent by grooving.
(*d*) Tests with flat bars and pressure vessels of section reduced 60 per cent by grooving.

In the case of the tensile bars the grooves were arranged on the two flat sides, and in the case of the pressure vessels they were in the form of spirals on the inside

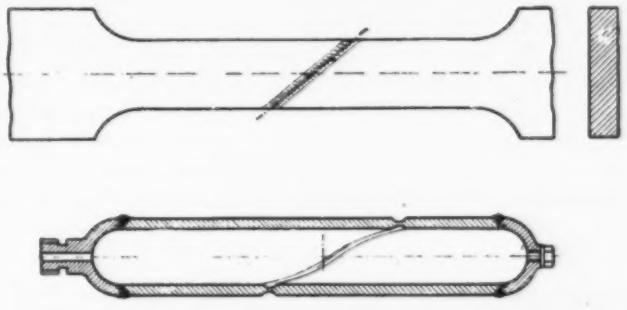

**Fig. 1—Form of test specimens employed**

and outside of the cylindrical wall, the inclination to the axis of the bar or the pitch of the spirals being varied as required. Possibility of error was offset by carefully finishing both the seamless tubes used in the construction of the models and by the grooves being ground all over. Care was also taken to make the cylindrical portion long enough to ensure the center part remaining unaffected by the external welds. Moreover, in order to obtain as homogeneous test specimens as possible all cylinders were normalized at a temperature of 900 C before the test.

Boiler plate with a tensile strength of 40 kg/mm²

* Excerpts from a report of investigations made by the Materials Testing Dept. of Brown, Boveri & Co., Ltd., Baden, Switzerland, as reported in *The Brown Boveri Review*, Vol. XXI, No. 6.

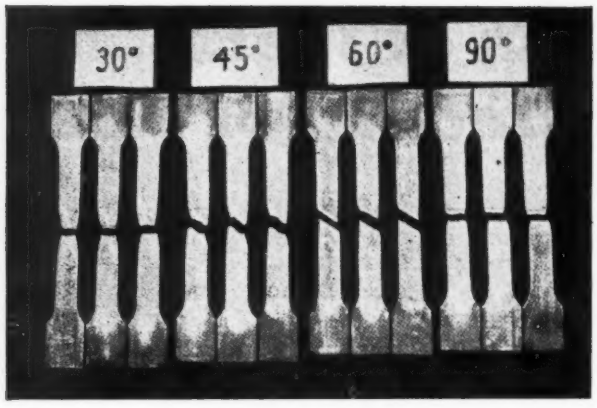


**Fig. 2—Failure of test bars grooved 20 per cent; the angle being indicated above each group**

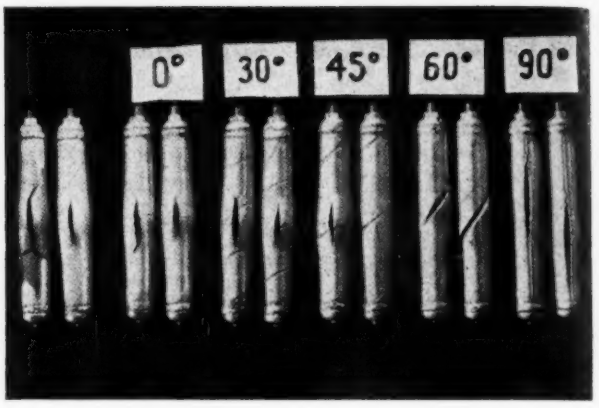


**Fig. 3—Failure of pressure vessels grooved 20 per cent; angle indicated above each group**

(56,880 psi) was used for the tensile bars and steel tubes having a tensile strength of 34 kg/mm² (48,348 psi) after annealing were employed for the pressure vessels. Coated electrodes with filler metal of a somewhat higher strength than the parent metal were used to weld the tensile bars.

*Comparison of Grooves and Welding Defects*

The purpose of these preliminary tests was to determine the effect of welding defects, grooves and notches in tensile bars, compared to welds of high quality. The reductions in section or welds were always arranged perpendicular to the direction of tension.

In the case of the reduced section specimens the joint efficiency was 0.79 and that of the bar purposely welded defectively was 0.83. Neither the defects in the welded joint nor the reduction in section resulted in any notable impairment of the tensile strength. On the other hand, the elongation definitely decreased with diminishing groove width. Welding defects behave like notches so that one is justified in applying the consequences of this observation not only to dynamic, but also to static stressing. The notch effect, which in the case of dynamic stresses leads to a substantial reduction of the fatigue limit, results in the long known increase in strength under static conditions of stress. In the present case this would indicate that a welding defect of nearly 20 per cent of the plate thickness has virtually no influence on the maximum static load and only affects the elasticity by 10 per cent. This again leads to the conclusion that in the case of statically stressed welds, slight welding defects such as pores or even slag inclusions have very little effect on the strength. As far as the following tests are concerned, however, it was proved that the grooves employed behaved fundamentally like defective welds, so that the results obtained with inclined grooves can also be applied to corresponding welds.

*Tests With Welded Flat Bars*

In the case of welds with an efficiency of 1, the joint is of the same or, as with the described tests, of greater strength than the parent metal. Consequently, due to the hindered transverse contraction of the weld, rupture must take place some distance from it. In this case it is not to be anticipated that the angle between the axis of the weld and the direction of tension will have any effect on the strength, inasmuch as the mechanical properties of the parent metal form the sole criterion on this score. These considerations were experimentally corroborated by the first two series of tests on tensile bars with and without machined welds.

The results, therefore, represent the behavior of joints with an efficiency of 1, whereby it must be emphasized that the welds were not heat treated. What is to be

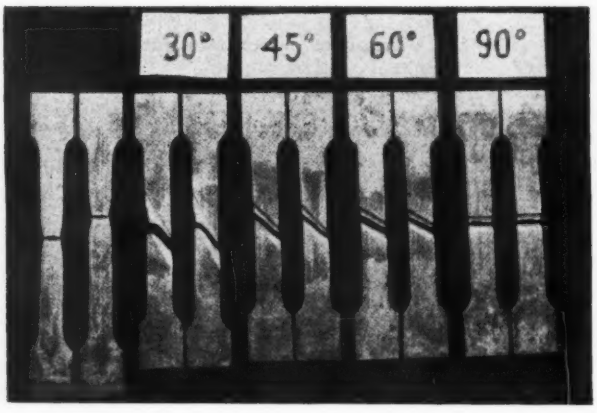


**Fig. 4—Failure of test bars grooved 60 per cent**

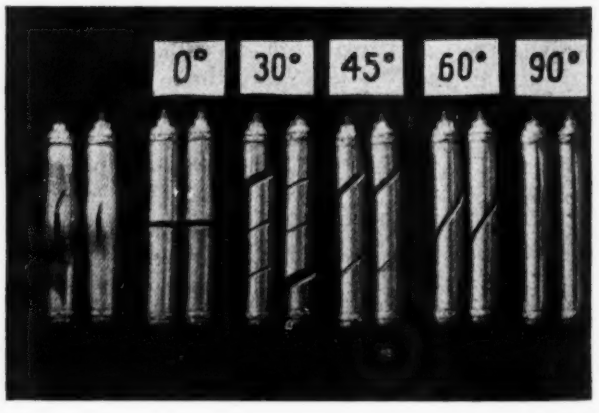


**Fig. 5—Failure of pressure vessels grooved 60 per cent**

borne in mind here is that given a joint efficiency of 1, the angle between the weld and the direction of stress is absolutely immaterial, so that there is no justification for inclining the weld.

*Tests on Flat Bars and Pressure Vessels*

In the case of the test specimens grooved for 20 per cent reduction in section, to correspond to a joint efficiency of 0.8, only a slight diminution was noticeable in the breaking loads of the bars and in particular of the pressure vessels, and the angle was of little importance.

In the case of the specimens grooved to correspond to a joint efficiency of 0.4 the load was substantially lower and depended largely on the inclination of the weld. Due to the groove, the tensile strength decreased rapidly between 0 and 60 deg, but with larger angles increased again by reason of the ensuing notch effect. This phenomenon is the same with both the axially pulled bar and the three-dimensionally stressed pressure vessel. If the groove is only slightly inclined to the direction of stress it is chiefly the nongrooved material that fails, regardless of the point of reduced section. As the angle increases the groove plays a more and more important

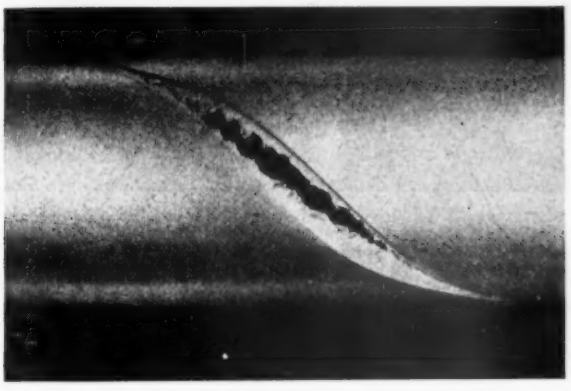

**Fig. 6—Pressure vessel with 20 per cent grooves inclined at 60 deg, after test, showing zig-zag break**

part, but it is not until it is perpendicular to the stress, or nearly so, that failure takes place exclusively in the reduced cross-section. In many test specimens in which the break was between the oblique and longitudinal it was found that the fracture jumps alternately from one direction to the other, thus resulting in a pronounced zig-zag break as shown in Fig. 6.

It was also possible to prove that the notch effect ceases below a definite limiting angle inasmuch as the grooves fracture in the direction of the groove due to shearing action. Fig. 8 shows a typical example of a pressure vessel shorn spirally in this way.

*Conclusions*

The gain in load achieved by inclining the weld to the direction of stress is definitely less than generally supposed.

In the case of bars with one-dimensional tensile stress and moderate reduction of section (20 per cent corresponding to a joint efficiency of 0.8) no advantage over the lengthwise weld is obtained until the angle is reduced below 45 deg and even then, in the most favorable case (angle of 0 deg) the gain does not exceed 5 per cent. Specimens reduced still further in section behave

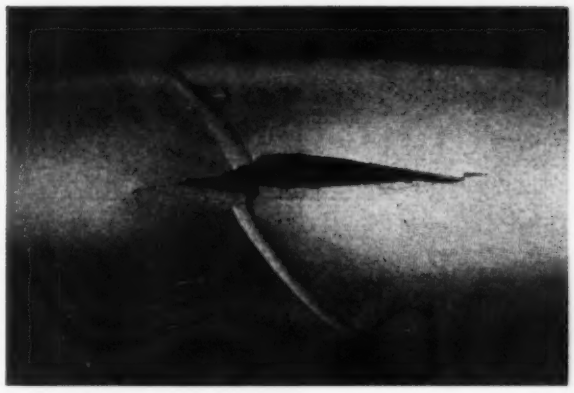

**Fig. 7—Pressure vessel with 20 per cent grooves inclined at 45 deg, after test**

fundamentally in the same manner. In such a case the increase in load is greater, but not until the angle becomes very small. Where the tested pressure vessels are concerned the gain over a lengthwise weld with a joint efficiency of 0.8 is no more than 2.1 per cent. With specimens reduced in section by 60 per cent large welding angles result in a considerable gain.

In general, therefore, it is found that the higher the joint efficiency the smaller the improvement and the larger the angle of the weld the smaller the gain.

Only in the case of very low joint efficiencies, such as may occur where steels of high strength and poor weldability are employed, is there any advantage to be obtained.

In connection with these results the significance of the joint efficiency again appears to be of special interest. With static stress, on which the calculation of pressure vessels is based in all national specifications, the joint efficiency serves to take into account differences in strength due to any internal or external defects in the welded joint which may have escaped notice during tests and inspection, as well as the additional stresses accruing from the welding process. In the foregoing tests the weld was considered as being systematically or continuously weakened. The results, however, can also be taken to refer to a local weakening of an otherwise perfect weld, such as a welding defect. Hence, under the conditions of test described here welding defects, which represent a reduction in cross-section to 20 per cent appeared to have practically no effect on the permissible load on the joint.

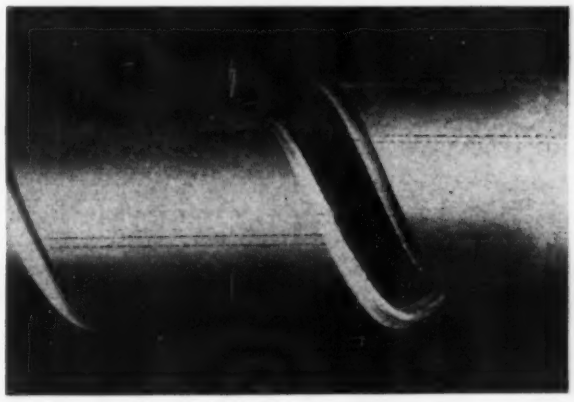

**Fig. 8—Pressure vessel with 60 per cent grooves inclined at 30 deg, after test**

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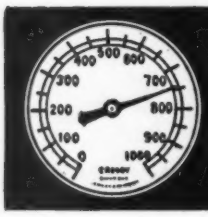

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# Some Factors in Design of Pulverized Coal Furnaces

MANY factors are involved in laying out a furnace for burning pulverized coal, some of which are governed by the characteristics of the coal, some by local conditions to be met, some by the size of unit and method of firing and others which are interdependent. Only a few of the major considerations will be covered in this brief review.

Of first importance in selecting such a furnace, is the method of slag removal, that is, whether the ash is to be removed from the bottom of the furnace in dry form or as molten slag. The latter is generally considered only for large units where the coal to be burned has a relatively low ash fusion temperature and where heavy sustained loads are anticipated. With such a furnace it is often assumed that about 50 per cent of the ash in the coal will be trapped in the slag pool.

The size of furnace depends primarily on the space required for complete combustion, which, in turn, is affected by the coal characteristics, the type of firing, and by the wall area necessary to provide the required heat-absorbing surface. In many of the large modern units up to fifty per cent of the heat given up by the fuel is absorbed by the furnace walls, mostly as radiant heat.

### *Furnace Shape*

Shape of furnace is governed mainly by the type of firing. Horizontal turbulent burners generally require wider furnaces, with relation to depth and height, than do tangential burners (corner firing) in which the furnaces are more nearly square. On the other hand, vertical firing as sometimes employed for low-volatile coals, necessitates furnace proportions that will permit a long U-shaped flame.

The amount and extent of water cooling to be installed in a furnace is governed mainly by the desired temperature of the gases leaving the furnace to enter the first boiler tube bank and superheater. The aim is to keep this temperature, if possible, below the fusion temperature of the ash in order to avoid troublesome slag accumulations in these areas. Fuel characteristics and size of unit also exert some influence.

Next, the nature of the water cooling must be determined; that is, whether the tubes are to be placed on wide centers with some refractory exposed to the flame in the furnace, finned tubes completely eliminating exposed refractory or plain tubes tangent to one another and completely covering the furnace walls.

The first arrangement, namely, widely spaced tubes with partly exposed refractory, can be justified with pulverized coal firing only for smaller units where high continuous ratings are not anticipated or where the cost of shutting down for deslagging the walls is not considered excessive. With larger units, especially those expected to operate over long periods at high rating, the cost of installing completely water-cooled walls can be justified.

In the early years of pulverized-coal firing, refractory furnaces without any water cooling were employed; but it was soon found that satisfactory operation without high refractory maintenance necessitated limiting the combustion rates to around 13,000 Btu per cu ft of furnace volume per hour and keeping the $CO_2$ in the leaving gases to not over 13 per cent.

### *Early Steps in Water Cooling*

The first departure from the all-refractory furnace was the introduction of a water screen above the ash hopper to cool the falling ash and permit its easy removal. This proved to be a most important step.

The next step involved cooling of the furnace walls, but designers were cautious as to the amount of cooling applied, starting in with tubes on wide centers mainly to reduce the cost of maintaining the refractory setting; for at that time there were some who believed that complete water cooling might result in unstable ignition—a contention which experience proved unfounded. Sidewall cooling followed.

Typical units of fifteen to twenty years ago employed a slag screen, widely spaced tubes on the rear wall exposing considerable refractory, finned tubes on the side walls, and no water cooling on the front wall. While some later units have employed this arrangement where operating conditions were not severe, the subsequent trend has been toward completely water-cooled furnaces for large and medium size units and often those of smaller capacity.

Up until about five years ago many large units were built for maximum furnace heat releases of 25,000 to 30,000 Btu per cu ft per hr or even higher, but experience with slag accumulations at these rates has resulted in a gradual trend toward lower heat releases of the order of 20,000 to 23,000 Btu per cu ft for such units and even lower where poor coals are involved. It is important that most efficient use be made of the heat-absorbing surfaces provided, which means clean surfaces.

### *Types of Firing*

Second only to cleanliness of the wall surface is the effect of the type of firing on the efficiency of combustion. The three well-known types of firing are the vertical burners, the horizontal turbulent burners and the corner or tangential firing which is especially adapted to large units. With the last-mentioned type the great turbulence and thorough mixing make possible less heating surface for a given gas temperature leaving the furnace. A recent and marked development with such firing has been arrangement for tilting the turbulent burners above or below the horizontal plane to control the temperature of the gases leaving the furnace and thus assist other means of control in maintaining a nearer approach to constant superheat over a wide range in load.

# The Gibbs and Helmholtz Functions for Compressed Liquid Water

By JAMES H. POTTER

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**The Johns Hopkins University**

IN ONE of the great scientific papers, Gibbs (1) described the thermodynamic functions $\chi$, $\zeta$ and $\psi$. The first is known today as "enthalpy," and is usually designated by $h$. The importance of enthalpy in engineering calculations is too widely known to need elaboration here; suffice it to say that during a steady-flow isentropic process the work done is equal to the decrease of enthalpy.

The functions $\zeta$ and $\psi$ have both been referred to as "free energy." Helmholtz (2) is credited with the introduction of the term "free energy." He applied it to the $\psi$ function, which is defined as the internal energy less the product of entropy and absolute temperature. The function $\zeta$, frequently represented by $Z$, is referred to as the "Gibbs Free Energy" or "Gibbs Function" to distinguish it from $\psi$. The Gibbs Function is defined as the enthalpy less the temperature-entropy product. Both the Gibbs and the Helmholtz functions are point functions, and have perfect differentials.

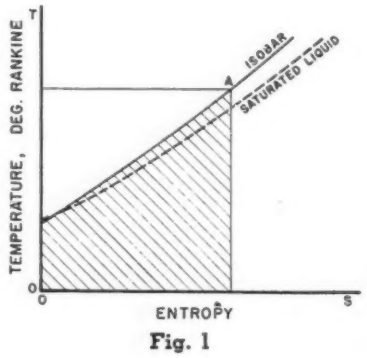


**Fig. 1**

The principal quantities used in this article have the following definitions and units:

$t$ = temperature, F
$T$ = temperature, Rankine = $(t + 459.69)$
$v$ = specific volume, cu ft per lb
$p$ = pressure, lb per sq in. abs (psia)
$U$ = internal energy, Btu per lb
$h$ = enthalpy, Btu per lb = $(U + pv)$
$S$ = entropy
$Z$ = Gibbs Function, Btu per lb = $(h - TS)$
$\psi$ = Helmholtz Function, Btu per lb = $(U - TS)$
$Q$ = heat added or rejected, Btu per lb
$W$ = work done, Btu per lb

Where the product $(pv)$ appears, it is understood to have been multiplied by 144/778.26, so that the units are Btu per lb. All values of the properties of liquid water are from the Keenan and Keyes tables (3).

Among many steam engineers it is customary to consider that an isobaric path in the $T$-$S$ plane runs horizontally from the saturated vapor line to the saturated liquid line, and then follows the saturated liquid line as the temperature falls. It has been shown by Keenan (4) and others that this is not the case. The saturated liquid line on the $T$-$S$ plane is a curve the orientation of which is concave upward. The isobars of high-pressure water lie above the saturated liquid line, and have the same concave upward trend. However, as the isobars are more flat, they intersect the saturated liquid line. It has been shown (4, 5) that the isobars intersect the saturated liquid line at 39.2 F, and at the saturation temperatures if the pressures are below the critical. The location of the high-pressure isobars affords a proof by areas (6) that readily explains the negative signs associated with both the Gibbs and the Helmholtz functions.

A $T$-$S$ plane for compressed liquid water is shown in Fig. 1. The point $A$ lies on a high-pressure isobar. The enthalpy $h_A$ is represented approximately by the area under the isobar between $A$ and the intersection with the saturated liquid line at 39.2 F, plus the area under the saturated liquid line from 39.2 F to 32 F. This area has been shown cross-hatched in Fig. 1. The $TS$ product is obviously equivalent to the area of the rectangle having a height $T_A$ and a base $S_A$. From inspection it is readily apparent that the $T \times S$ area exceeds the area which represents $h_A$.[1]

Hence, $Z = (h - TS)$ is normally negative.

Although a similar technique is not available to demonstrate that the Helmholtz Function is normally negative, this statement is readily proved. Inasmuch as $U = (h - pv)$, it is proper to write:

$$\psi = (h - pv) - TS = Z - pv$$

as $Z$ has been shown to be negative, then $(Z - pv)$ must also be negative for all positive values of $p$.

## The Gibbs Function

Many authors have stressed the applications of the $Z$ function in physical chemistry. It is well to remember that work may be done in a system by other than mechanical means. Epstein (7) offers the following proof of the usefulness of the $Z$ function for a nonflow process:

Consider a reversible thermodynamic system depending upon $p$ and $T$ and also upon some nonmechanical variables such as electricity or magnetism. If the element of work done by these nonmechanical variables is $DW'$, then the total work element is given by:

$$DW = Pdv + DW'$$

and the nonflow equation may then be written:

$$dU = TdS - Pdv - DW'$$

A Legendre transformation of the first and second terms on the right gives:

$$dU = d(TS) - SdT - d(pv) + vdp - DW'$$

whence:

$$dZ = vdp - SdT - DW'$$

If the temperature and pressure are maintained constant, this equation reduces to:

$$dZ = -DW' \qquad (1)$$

The nonflow case may then be summed up by the statement that the nonmechanical work produced during a reversible isothermal isobaric process is equal to the decrease of the Gibbs Function.

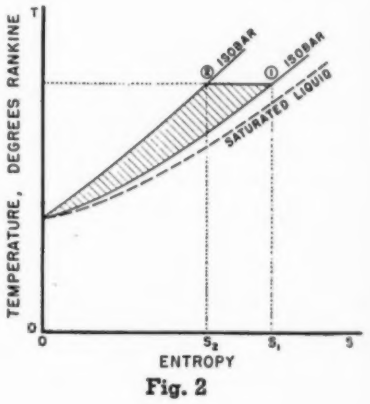


**Fig. 2**

The steady-flow case is less complex, and has more immediate utility for the mechanical engineer. Recall that the work done under steady flow is expressed by

$$W = -\int_{P_1}^{P_2} vdp = Q + (h_1 - h_2)$$

If the temperature is held constant, then:

$$Q = T(S_2 - S_1)$$

and:

$$W = (h_1 - TS_1) - (h_2 - TS_2) = (Z_1 - Z_2) \qquad (2)$$

This important equation indicates that the useful mechanical work accomplished in a steady-flow isothermal process is equal to the change in the Gibbs Function.

A graphical proof of this equation is also available. An isothermal pressure rise is

[1] This analysis holds for the Gibbs Function at 32 F even though the values for $Z$ are positive. At this temperature the isobar lies inside the saturated liquid line, and the $TS$ product is smaller in magnitude than the enthalpy. From Table 1, it is apparent that this method does not hold for pressures above 2000 psia at 100 F.

shown on the $T$-$S$ plane in Fig. 2.[1] In order to satisfy the more general case, the starting point (*1*) is taken on an isobar at a pressure exceeding the saturation pressure at the temperature $T_1$. It is understood, however, that the point (*1*) could lie on the saturated liquid line. From earlier considerations it is known that $Z_2$ has a value equivalent to the area under the $p_2$ isobar to 39.2 F plus the area under the saturated liquid line from 39.2 to 32 F, less that of $T_2S_2$. Also $Z_1$ has a value equivalent to the area under the $p_1$ isobar to 39.2 F, plus the area under the saturated liquid line from 39.2 F to 32 F, less that of $T_1S_1$. Actually the value of $Z_2$ is represented by the area bounded by $T_2$, the temperature axis, the $P_2$ isobar and the saturated liquid line. Similarly, the value of $Z_1$ can be shown to be the area bounded by $T_1$, the temperature axis, the $P_1$ isobar, and the saturated liquid line. Hence the work done is the difference in the areas of these two quadrilaterals, or the area shown cross-hatched in Fig. 2.

Rapid solution of problems in steady-flow isothermal feed-pump work is facilitated by the use of the chart shown in Fig. 3. Here $(Z - Z_f)$ has been plotted against Fahrenheit temperature, the isobars forming a family of similar curves. The quantity $Z_f$ is the Gibbs Function at saturated liquid. The difference $(Z - Z_f)$ is positive, and the isothermal feed-pump work between saturated liquid and a given pressure is found by taking a vertical distance from the abscissa to that pressure. Similarly, the isothermal feed-pump work between any two isobars is the vertical distance between the isobars along the given temperature line.

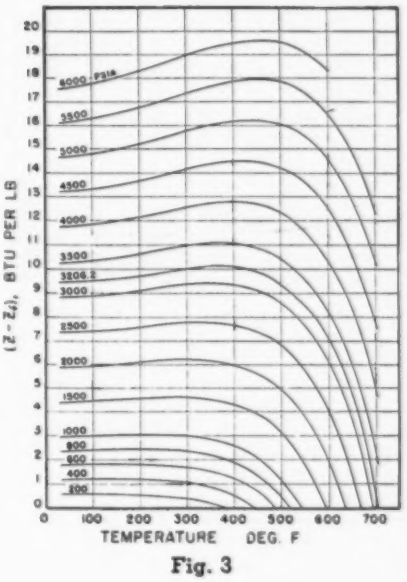

Fig. 3

### The Helmholtz Function

Consider the non-flow equation:

$$dU = TdS - PdV$$

substituting $d(TS) - SdT$ for $TdS$ yields:

[1] Fig. 2 was prepared to show the isothermal pressure change at a temperature much above 39.2 F. For the sake of closer approximation to scale, the isobars are shown to terminate almost at the temperature axis.

**TABLE 1 — THE GIBBS & HELMHOLTZ FUNCTIONS FOR COMPRESSED LIQUID WATER**

**Z AND $\psi$ IN BTU/LB**

| Temp.deg.f | | 32 | 100 | 200 | 300 | 400 | 500 | 600 | 620 | 640 | 660 | 680 | 690 | 700 | 705.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sat.Liquid | $Z_f$ | .00 | -4.50 | -25.84 | -62.35 | -111.94 | -173.13 | -244.6 | -260.0 | -275.8 | -292.1 | -308.4 | -316.8 | -325.4 | -330.0 |
| | $\psi_f$ | .00 | -4.50 | -25.88 | -62.57 | -112.79 | -175.70 | -251.4 | -268.1 | -285.7 | -304.3 | -323.7 | -334.4 | -346.5 | -359.8 |
| 200 psia. | Z | +.59 | -3.93 | -25.29 | -61.96 | | | | | | | | | | |
| | $\psi$ | .00 | -4.53 | -25.91 | -62.61 | | | | | | | | | | |
| 400 " | Z | +1.19 | -3.32 | -24.65 | -61.31 | -111.44 | | | | | | | | | |
| | $\psi$ | +.01 | -4.51 | -25.88 | -62.60 | -112.82 | | | | | | | | | |
| 600 " | Z | +1.77 | -2.68 | -24.04 | -60.66 | -110.73 | | | | | | | | | |
| | $\psi$ | .00 | -4.47 | -25.88 | -62.59 | -112.79 | | | | | | | | | |
| 800 " | Z | +2.34 | -2.10 | -23.42 | -60.03 | -110.06 | -172.67 | | | | | | | | |
| | $\psi$ | -.02 | -4.48 | -25.88 | -62.60 | -112.81 | -175.69 | | | | | | | | |
| 1000 " | Z | +2.92 | -1.50 | -22.84 | -59.35 | -109.38 | -171.91 | | | | | | | | |
| | $\psi$ | -.03 | -4.48 | -25.91 | -62.57 | -112.81 | -175.68 | | | | | | | | |
| 1500 " | Z | +4.38 | -0.03 | -21.30 | -57.73 | -107.65 | -170.00 | | | | | | | | |
| | $\psi$ | -.04 | -4.49 | -25.89 | -62.54 | -112.78 | -175.62 | | | | | | | | |
| 2000 " | Z | +5.86 | -1.47 | -19.75 | -56.11 | -105.98 | -168.15 | -242.6 | -259.0 | | | | | | |
| | $\psi$ | -.03 | -4.46 | -25.87 | -62.52 | -112.81 | -175.61 | -251.2 | -268.0 | | | | | | |
| 2500 " | Z | +7.37 | +2.91 | -18.25 | -54.57 | -104.30 | -166.30 | -240.5 | -256.8 | -273.6 | -291.4 | | | | |
| | $\psi$ | +.02 | -4.50 | -25.88 | -62.56 | -112.81 | -175.58 | -251.2 | -267.9 | -285.5 | -304.0 | | | | |
| 3000 " | Z | +8.86 | +4.38 | -16.73 | -52.97 | -102.57 | -164.50 | -238.4 | -254.7 | -271.4 | -289.0 | -307.0 | -316.3 | | |
| | $\psi$ | +.06 | -4.49 | -25.87 | -62.54 | -112.75 | -175.58 | -251.0 | -267.8 | -285.1 | -303.6 | -323.0 | -333.6 | | |
| 3206.2 | Z | +9.47 | +5.03 | -16.08 | -52.27 | -101.84 | -163.75 | -237.4 | -253.6 | -270.3 | -287.9 | -305.7 | -315.0 | -324.7 | -330.0 |
| | $\psi$ | +.07 | -4.45 | -25.85 | -62.49 | -112.71 | -175.57 | -250.8 | -267.6 | -284.9 | -303.3 | -322.4 | -332.7 | -344.5 | -359.8 |
| 3500 " | Z | +10.29 | +5.84 | -15.21 | -51.37 | -100.87 | -162.68 | -236.3 | -252.4 | -269.1 | -286.5 | -304.3 | -313.5 | -323.0 | -328.0 |
| | $\psi$ | +.04 | -4.50 | -25.86 | -62.51 | -112.71 | -175.55 | -250.9 | -267.5 | -284.9 | -303.1 | -322.1 | -332.1 | -342.8 | -348.8 |
| 4000 " | Z | +11.74 | +7.35 | -13.68 | -49.80 | - 99.15 | -160.78 | -234.2 | -250.2 | -266.8 | -284.1 | -301.7 | -310.8 | -320.2 | -325.3 |
| | $\psi$ | +.04 | -4.45 | -25.84 | -62.51 | -112.65 | -175.42 | -250.7 | -267.3 | -284.5 | -302.7 | -321.3 | -331.2 | -341.5 | -347.1 |
| 4500 " | Z | +13.19 | +8.83 | -12.17 | -48.18 | - 97.45 | -158.90 | -232.0 | -248.0 | -264.6 | -281.9 | -299.2 | -308.3 | -316.5 | -322.5 |
| | $\psi$ | +.05 | -4.47 | -25.82 | -62.45 | -112.60 | -175.31 | -250.4 | -267.0 | -284.3 | -302.4 | -320.8 | -330.5 | -340.4 | -345.9 |
| 5000 " | Z | +14.64 | +10.30 | -10.63 | -46.61 | - 95.77 | -157.07 | -229.9 | -246.0 | -262.4 | -279.6 | -296.8 | -305.7 | -315.0 | - 19.8 |
| | $\psi$ | +.06 | -4.41 | -25.78 | -62.44 | -112.55 | -175.23 | -250.2 | -266.9 | -284.0 | -302.1 | -320.3 | -329.8 | -339.7 | -345.0 |
| 5500 " | Z | +16.08 | +11.81 | - 9.10 | -45.00 | - 94.11 | -155.24 | -228.1 | -244.0 | -260.4 | -277.4 | -294.8 | -303.7 | -312.9 | -317.8 |
| | $\psi$ | +.07 | -4.35 | -25.74 | -62.38 | -112.53 | -175.13 | -250.3 | -266.8 | -283.9 | -301.8 | -320.2 | -329.7 | -339.5 | -344.8 |
| 6000 " | Z | +17.55 | +13.30 | - 7.56 | -43.36 | - 92.44 | -153.58 | -226.2 | | | | | | | |
| | $\psi$ | +.11 | -4.30 | -25.68 | -62.28 | -112.48 | -175.20 | -250.2 | | | | | | | |

**TABLE 2 — AVERAGE VALUES OF THE HELMHOLTZ FUNCTION AT CONSTANT TEMPERATURE**

| Temperature,deg.f. | 100 | 200 | 300 | 400 | 500 | 600 | 620 | 640 | 660 | 680 | 690 | 700 | 705.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\psi_{av}$, BTU/# | -4.46 | -25.85 | -62.52 | -112.71 | -175.49 | -250.75 | -267.49 | -284.73 | -303.03 | -321.72 | -331.75 | -342.13 | -350.2 |
| Variation of $\psi$ max. from $\psi$ av., % | 1.57 | 0.232 | 0.144 | 0.098 | 0.120 | 0.251 | 0.224 | 0.351 | 0.429 | 0.622 | 0.814 | 1.29 | 0.274 |
| Variation of $\psi$ min. from $\psi$ av., % | 3.59 | 0.657 | 0.384 | 0.204 | 0.205 | 0.223 | 0.262 | 0.281 | 0.396 | 0.466 | 0.603 | 0.760 | 0.154 |

whence:

$$dU = d(TS) - SdT - Pdv$$

$$d\psi = -SdT - Pdv \qquad (3)$$

for an isothermal process $dT = 0$, and

$$d\psi = -dW$$

hence:

$$\psi_1 - \psi_2 = W \qquad (4)$$

It has been demonstrated by Epstein (7) and others that in the case of a reversible

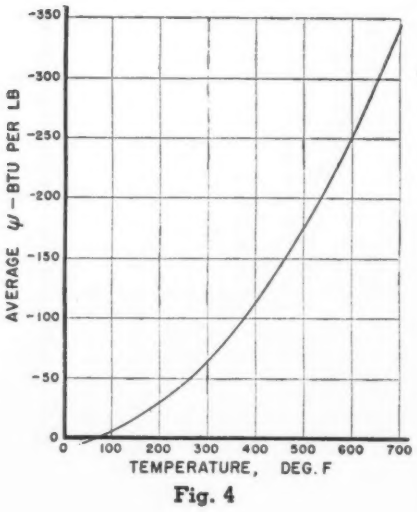


**Fig. 4**

isothermal process the maximum work is represented by the difference in the Helmholtz Function. Equation (4) therefore requires that the process be both isothermal and reversible in order to yield maximum work. The values for $\psi$ for compressed liquid water are given in Table 1.

As the isothermal variation of $\psi$ with respect to pressure is very small, it has been found convenient to indicate the trend of $\psi$ with temperature. Average values of $\psi$ have been plotted against temperature in Fig. 4. This curve affords a rough means for finding values of $\psi$ at temperatures intermediate to those for which actual points were computed. A measure of the error involved in the use of Fig. 4 is given in Table 2. Here average values of $\psi$ are cited and the per cent variation of the maximum and minimum values from these averages are shown.

### *Conclusions*

The Gibbs and Helmholtz functions for compressed liquid water are given in Table 1. It is noteworthy that, in the absence of a phase change, there is very little variation of the Helmholtz Function with pressure.

Callendar (8) has included some values of $G = -Z$ in his latest tables. Only a small range has been explored by him, and his values are only for saturated liquid. At 100 F and 200 F the Callendar values check those listed in Table 1.

The change of the Gibbs Function during a steady-flow reversible isothermal process is of interest as it represents the feed-pump work. Using Fig. 3, the calculations involved in such a process are reduced to a simple chart reading technique.

The author wishes to express his thanks to Professor J. C. Smallwood of the Johns Hopkins University for his encouragement and helpful suggestions.

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## National Fuel Efficiency Council Reports on Progress

Fuel savings ranging from 3 to 35 per cent in industrial plants, office buildings, apartment houses, Government buildings, schools and by various other commercial consumers were reported at a recent meeting of the National Fuel Efficiency Council with officials of the Bureau of Mines in Washington. To date nearly ten thousand plants throughout the country have been visited and surveyed by volunteer engineers working under the Efficiency Program; pledges of cooperation have been secured from the operators; and a "waste chaser" has been designated for each plant to put into effect the information provided.

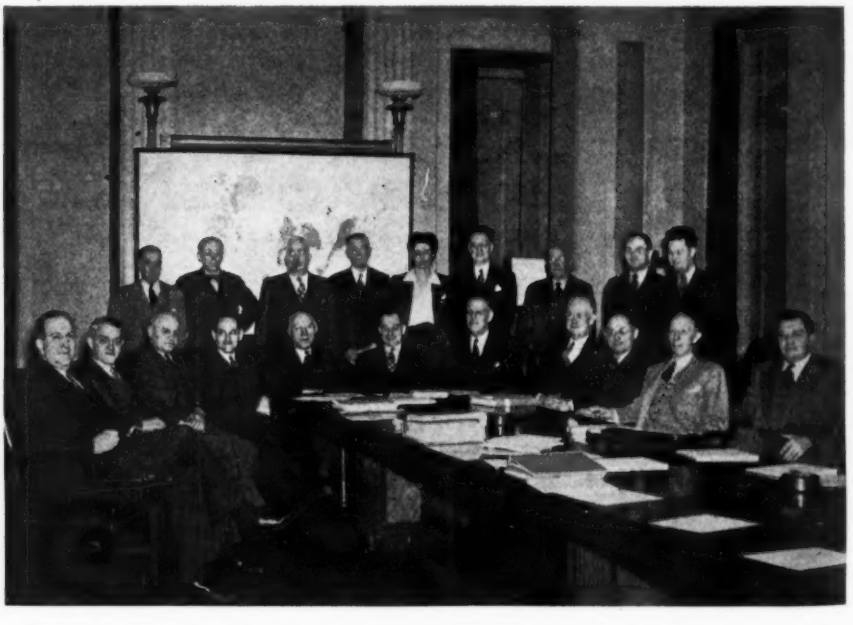
At the outset of the campaign, a goal was established to save 29 million tons of coal a year and proportionate amounts of oil and natural gas. Although overall figures as to actual savings are not yet attainable, substantial progress toward the goal was disclosed at the meeting during which the accompanying photograph was taken.

Indicative of the wide range of fuel consumers cooperating was a distribution breakdown of 1300 pledges in seven areas showing: schools and colleges, 19.6 per cent; apartments, 4.2 per cent; hotels, 2.5 per cent; stores, office buildings and theatres, 13.9 per cent; laundries and drycleaning establishments, 1.7 per cent; libraries, post offices, etc., 4.7 per cent; hospitals, clubs, churches and institutions, 8.7 per cent; factory power plants, 35.8 per cent; and miscellaneous, 8.9 per cent.

### *Government Departments Show Substantial Fuel Savings*

Representative yearly savings by Government departments in Washington, compiled on a degree-day basis, were 25 per cent for public buildings, 20 per cent by the Hydrographic Office, 30 per cent by the Navy Department, 33 per cent by the Munitions Bureau and 16 per cent by temporary buildings.

Still expanding their field organization, the directors of the National Fuel Efficiency Program have now appointed 181 area coordinators throughout the country with supervision over 5000 regional engineers—all volunteers from industry. The coordinators, in turn, have appointed 726 persons to their advisory committees and 34 "quiz sheets," providing fuel-efficiency information, have already been distributed. Two more are being printed and twelve additional sheets are being prepared.



**Seated left to right: J. E. Tobey, R. A. Sherman, H. K. Kugel, J. F. Barkley, Dr. A. C. Fieldner, Thos. C. Cheasley, Dr. R. R. Sayers, W. G. Christy, O. F. Campbell, C. A. Reed, Carroll F. Hardy.**

**Standing left to right: S. M. Walker, H. J. C. MacDonald, Kenneth M. Waddell, F. M. Howard, Fay D. Edwards, J. H. Burton, G. M. S. Tait, R. E. Morgan and G. M. Hayes.**

# Steam Turbine-Driven Locomotive

THE first direct-drive steam-turbine locomotive to be built in this country is now undergoing main-line, long-distance service trials on the Pennsylvania Railroad. Developed through the joint efforts of the Westinghouse Electric & Mfg. Company, the Baldwin Locomotive Works and the Pennsylvania Railroad, the new locomotive is capable of developing 6900 hp and a speed of 100 mph when hauling a 16-car train.

Steam turbines have been employed to drive locomotives in a number of instances abroad, notably on the London, Midland and Scottish Railway System, where they have been in service since 1933. However, the power is only about 2000 hp which is insufficient to be competitive with the efficient compound reciprocating-engine locomotives used on that system, or the very much larger single-expansion engines employed on American railroads.

The largest diesel-electric passenger locomotive yet built is a three-unit type developing 6000 hp and having an overall length of 223 ft compared with 122 ft 7 in. for the new turbine locomotive.

The new locomotive employs a conventional fire-tube boiler, capable of producing 95,000 lb of steam per hour at 310 psi, 750 F. There are two non-condensing turbines—one for going forward and the other for reverse. The former is of the impulse type employing a Curtis stage and five full-admission Rateau stages. It supplies power through double-reduction gears to each of the two middle driving axles. The reverse turbine is a single-stage unit, overhung on an extension of the reverse-gear pinion shaft.

Steam enters the forward turbine through four 3-in. pipes, each connected to a nozzle group covering approximately 25 per cent of the peripheral area of the Curtis stage blading, and each inlet pipe is connected through a throttle-valve to the steam header. There are four cam-operated valves for control of the steam to the forward turbine. One inlet pipe with cam-operated throttle valve serves the reverse turbine. A single lever in the cab controls speed in both directions.

While the forward turbine is solidly connected to the high-speed pinion, the reverse turbine is engaged with this pinion only during reverse operation, through a hydraulically actuated, positive-engagement clutch. Both turbines are supported from the gear case which, in turn, is supported from the main locomotive frame at three points.

At a train speed of 100 mph, the forward turbine turns at 9000 rpm and at a maximum backward train speed of 22 mph, the reverse turbine turns at 8300 rpm while developing 1500 hp.

Tests have shown the turbine locomotive to require less time to accelerate a 1200-ton, 16-car train up to high speeds than either the diesel-electric or the reciprocating-engine types, which is important in stepping up average speed when numerous stops and slowdowns are involved.

The curves in Fig. 2, from a paper by Charles Kerr, Jr., Consulting Transportation Engineer of Westinghouse, represent a comparison between the turbine locomotive and the conventional reciprocating engine locomotive as to steam consumption at various speeds. From this it will be noted that although the present

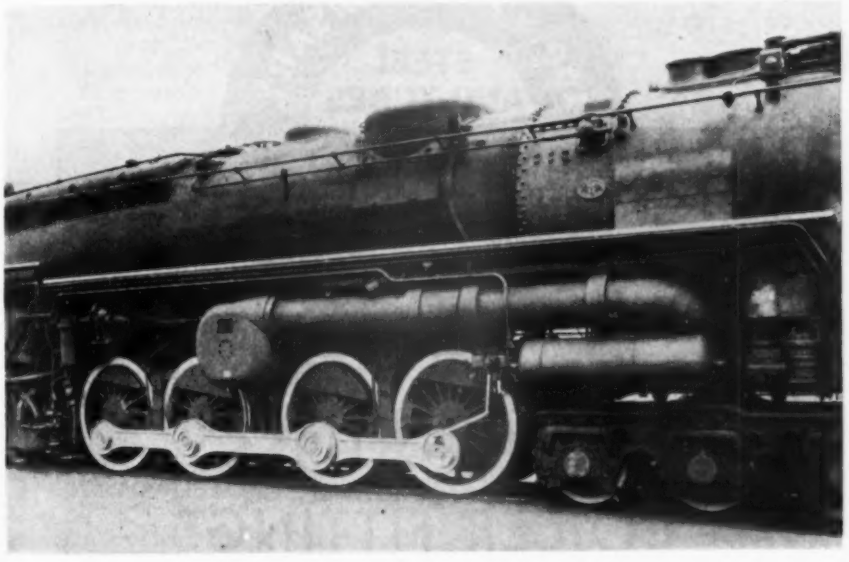


**Fig. 1—Steam inlet side of turbine locomotive**

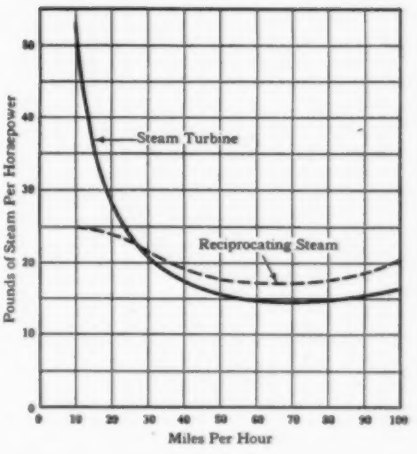



**Fig. 2—Steam consumptions of turbine and reciprocating engine locomotive compared**

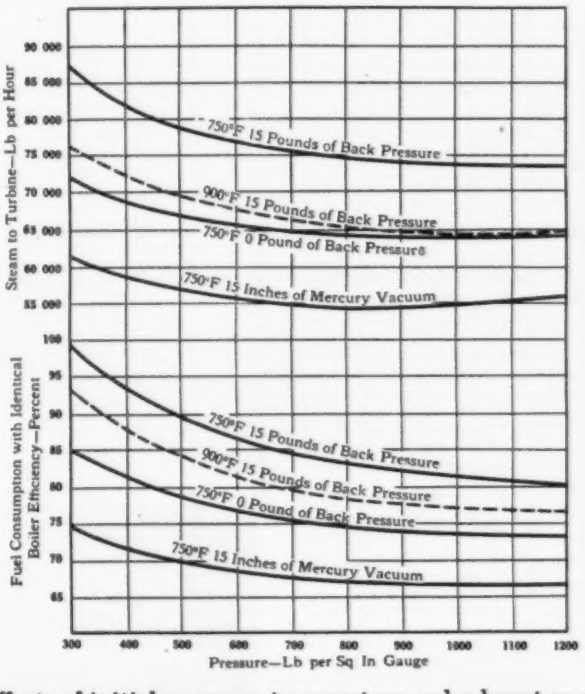

Steam to Turbine—Lb per Hour
750°F 15 Pounds of Back Pressure
900°F 15 Pounds of Back Pressure
750°F 0 Pound of Back Pressure
750°F 15 Inches of Mercury Vacuum
Fuel Consumption with Identical Boiler Efficiency—Percent
750°F 15 Pounds of Back Pressure
900°F 15 Pounds of Back Pressure
750°F 0 Pound of Back Pressure
750°F 15 Inches of Mercury Vacuum
Pressure—Lb per Sq In Gauge

**Fig. 3—Effects of initial pressure, temperature and exhaust on economy**

turbine locomotive is at a disadvantage for speeds under about 25 mph, it has greater economy at higher speeds such as are demanded in main-line passenger service. However, for slower freight service the gear reduction could be made more favorable to efficiency at low speeds.

It is pointed out that the ultimate limit in the power of a steam locomotive is the capacity of the boiler. With geared turbine drive, locomotives can be built with smaller wheels which permits boilers of larger diameter, and the shorter wheel base allows greater grate area under the boiler. Moreover, a turbine can utilize much higher steam temperatures than those possible with a reciprocating engine. Fig. 3 shows how total steam temperature, steam pressure and exhaust-pressures affect the efficiency of the turbine drive and point the way to further progress in such development.

*High-Pressure Pulverized-Coal-Fired Locomotives*

Announcement of another important development in the locomotive field is contained in the current *Bulletin* of Bituminous Coal Research. This refers to a design of pulverized-coal-fired high-pressure, turbine-electric locomotive being built for a group of nine railroads by the General Electric Company. The B&W water-tuber boiler will supply steam to a G. E. turbine of 5400 hp. Another year of engineering and construction will probably be required before the new unit is ready for track trials.

A research program on improved coal-burning locomotives, backed by six coal-originating railroads has recently been undertaken by Bituminous Coal Research. For this purpose over a million dollars has already been subscribed.

## Littlebrook Power Station

Censorship imposed by the Defense Regulations in England has heretofore precluded publication by the British technical press of information pertaining to details of power plant construction, hence engineering readers in both Great Britain and the United States know very little of what has been going on in the power field in that country.

However, *The Electrician* (London) of February 2, 1945, carries a description of the Littlebrook Power Station of the Kent Electric Power Co., Ltd., which was put into service shortly after the start of the war but around which the veil of secrecy has just been lifted.

This station has few if any unusual features but it does indicate certain practices which are understood to have been reflected in other wartime power-plant construction in England. Among these are large turbine units, moderate steam pressure and temperature, and the initial employment of both stokers and pulverized coal firing in the same station—a feature seldom found in new power plants on this side of the Atlantic.

The Littlebrook Station has a capacity of 120,000 kw, furnished by one 60,000-kw, B.T.H. two-cylinder, 1500-rpm turbine-generator and two 30,000-kw 3000-rpm Parsons double-exhaust units. The large unit employs five stages of extraction feedwater heating to a final temperature of 355 F, whereas the two smaller units each have four extraction stages with the same final feedwater temperature.

Steam is supplied at 600 psi, 825 F by six boilers, each of 256,000 lb per hr evaporative capacity. Three of these are B&W units of the three-pass vertical-header type, fired by chain-grate stokers, and three are pulverized-coal-fired International Combustion units of the four-drum bent-tube type provided with fin-tube furnace walls and corner firing. Pulverized coal is supplied to two of the boilers by four roller mills and to one boiler by two horizontal ball mills.

All the boilers have economizers and the gases from the three stoker-fired units pass through Davidson dust collectors, whereas those from the pulverized-coal-fired units are handled by electrostatic dust precipitators. Ash is carried away by a hydro-jet system.

Under the announced plans of the Central Electricity Board, the capacity of Littlebrook Station is to be doubled in the near future which will bring it up to two-thirds the ultimate capacity for which it was originally laid out.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## Changing Climate

*The Anthracite Institute Bulletin*, under date of January 10, 1945, quotes as follows from a report of investigations by J. B. Kincer of the U. S. Weather Bureau in support of a contention that our climate is changing:

"We are in a period of abnormal warmth which has come on more or less gradually over a period of many years. This study shows that temperature trends in the middle latitudes of the Northern Hemisphere have been prevailingly high for a long time. When the short-period fluctuations in the record are smoothed into long-time trends (the longest available covering more than 100-years) there is a somewhat irregular, but very definite, upward swing in the curves, shown to have been in progress for more than half a century; and there is as yet no evidence of a recession.

"The records for the different seasons of the year show that the winters are the most erratic, with up and down trends of greater frequency and shorter duration than the other seasons. For the spring and fall the trends have been uniformly upward with fewer interruptions by short cold spells. The curves for the fall season show a remarkably steady upward trend for nearly a century; that is, for nearly 100 years our fall seasons have been trending progressively to warmer. The summer curve shows a slight recession from about 1875 to 1912, but thereafter a moderate rise.

"For fall, winter and spring seasons the averages in temperature in recent years have been from 2.5 to 4 deg higher than similar averages sixty or seventy years ago."

It is Mr. Kincer's belief that the swing to higher temperatures began in this country about 1875 and in Europe twenty years earlier.

Obviously, this report was written before the recent prolonged cold spell.

## External Feedwater Treatment

The article on feedwater treatment at the Dow Chemical Company, in the December issue, states: "The writers believe that these installations are the only ones of their type installed in this country or abroad, where practically 100 per cent of the feedwater is chemically treated by external means for boilers operating at 1400 psi."

We would like to take exception to this statement by pointing out that the 1400-psi Deepwater Station of the E. I. du Pont de Nemours & Co., Inc., as described by Mr. Carmichael at the A.S.M.E. Atlanta Meeting several years ago, has its feedwater treated by first removing the silica, then passing through an external Zeo-Karb sodium system, plus supplementary treatment. The makeup is practically 100 per cent.

HENRY H. WILKINSON,
The Permutit Company

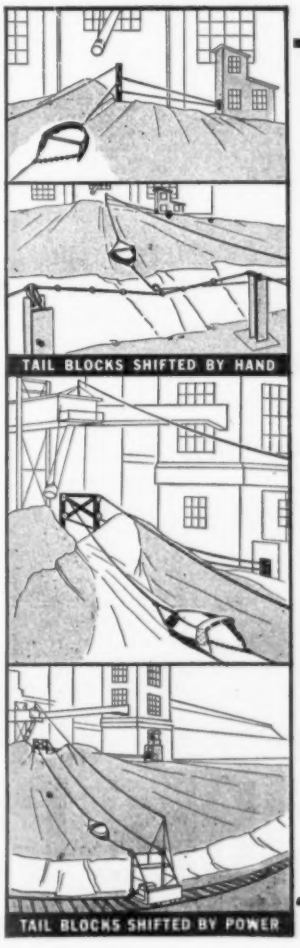
# Stocks and Consumption of Bituminous Coal

Stocks of bituminous coal held in consumer's bins as of February 1, 1945, and consumption of bituminous coal during January 1945, are reported in the following tables compiled by the Solid Fuels Administration. The number of days' supply is an average, based on January 1945 rate of consumption. As to the stocks held by individual consumers, some have a great deal more coal in storage than others, and the stocks of some particular kinds of coals are not as great as others. Also, some consumers have no storage facilities.

| | Feb. 1, 1945, tons | Jan. 1, 1945, tons | Average Number Days' Supply, Feb. 1, 1945 | Average Number Days' Supply, Jan. 1, 1945 | Per Cent Change in Days' Supply |
|---|---|---|---|---|---|
| Stocks held by | | | | | |
| Electric power utilities | 14,377,000 | 16,305,000 | 61 | 72 | −15.3 |
| By-product coke ovens | 5,692,000 | 6,112,000 | 22 | 24 | − 8.3 |
| Steel and rolling mills | 666,000 | 701,000 | 19 | 21 | − 9.5 |
| Coal gas retorts | 214,000 | 243,000 | 46 | 55 | −16.4 |
| Cement mills | 494,000 | 538,000 | 52 | 47 | +10.6 |
| Other industries | 13,649,000 | 15,653,000 | 31 | 38 | −18.4 |
| Railroads (Class I) | 11,311,000 | 12,918,000 | 29 | 34 | −14.7 |
| Retail dealers' stocks | 3,337,000 | 4,734,000 | 6 | 11 | −45.5 |
| Grand totals and averages | 49,740,000 | 57,204,000 | 26 | 32 | −18.7 |

CONSUMPTION OF BITUMINOUS COAL DURING JANUARY 1945

| | Month of Jan. 1945, Tons | Month of Dec. 1944, Tons | Per Cent of Change |
|---|---|---|---|
| Consumption by | | | |
| Electric power utilities | 7,327,000 | 7,066,000 | + 3.7 |
| By-product coke ovens | 7,933,000 | 7,984,000 | − 0.6 |
| Beehive coke ovens | 714,000 | 632,000 | +13.0 |
| Steel and rolling mills | 1,078,000 | 1,022,000 | + 5.5 |
| Coal gas retorts | 145,000 | 138,000 | + 5.1 |
| Cement mills | 296,000 | 352,000 | −15.9 |
| Other industries | 13,478,000 | 12,861,000 | + 4.8 |
| Railroads (Class I) | 12,011,000 | 11,758,000 | + 2.2 |
| Retail dealer deliveries | 16,302,000 | 13,373,000 | +21.9 |
| Grand total | 59,284,000 | 55,186,000 | + 7.4 |


**STORING MORE COAL NOW?**

You Can Do It Better—and Save Manpower with a

**SAUERMAN ONE-MAN SYSTEM**

Simple • Safe • Economical

The Sauerman Power Drag Scraper is a one-man machine that serves as a self-loading conveyor with large handling capacity and long reach, assuring full use of all space . . . a cable controlled, bottomless bucket that rides on the material it is to move. Pulled forward, it loads. Pulled backward it empties.

In storing, coal is dumped in front of a head post and distributed from this initial pile in compact layers—building a storage pile free of combustion hazards. In reclaiming the scraper is turned around and the coal dragged back.

Two types of installations with hand shifted tail blocks or power shifted tail blocks, as illustrated at left, provide greater storage capacity on areas of any size or shape.

*It costs but a few cents per ton to store and reclaim coal the better Sauerman way.*

Our catalog illustrates and describes many typical Sauerman installations. It is yours for the asking.

**SAUERMAN BROS., INC.**

550 So. Clinton St. Chicago 7, Ill.

So many plant operators have discovered how really good S. E. Co. Coal Scales are that we're finding it difficult to keep abreast of demand in spite of increased plant facilities. At first we could promise three month delivery . . . then it was four months . . . then six—and now the best we can do is nine months. We're sorry—but remember, S. E. Co. Coal Scales are worth waiting for. Stock Engineering Co., 713 Hanna Bldg., Cleveland 15, Ohio

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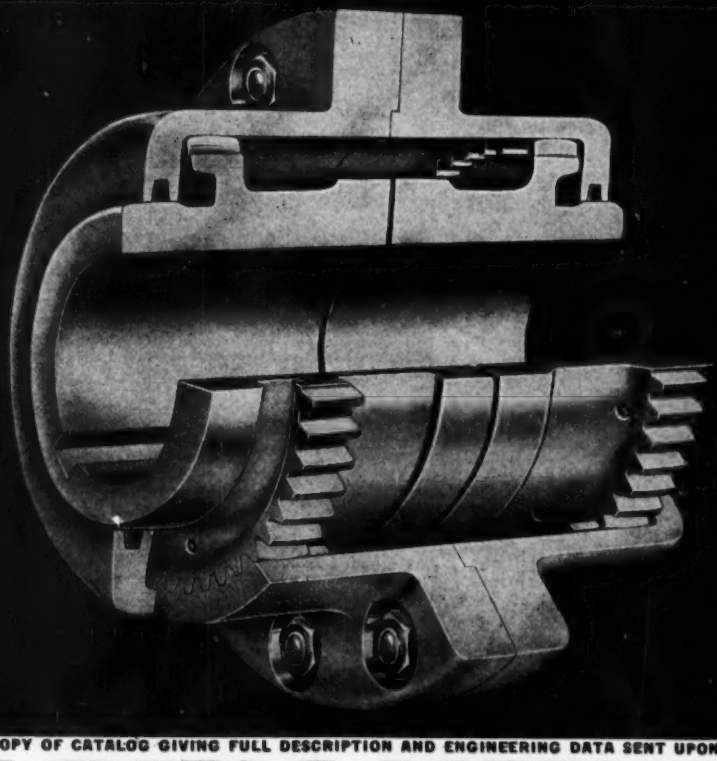
S.E.Co. Coal Valves and Coal Scales, CONICAL Non-Segregating Coal Distributors

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

# NEW CATALOGS AND BULLETINS

**Any of these publications will be sent on request.**

## Air Handling Equipment

B. F. Sturtevant Company has issued a 199-page pocket size catalog and data book entitled "What We Make" which describes a complete line of air-handling equipment and its application to industrial systems such as heating, ventilating, air conditioning, drying, dust control, etc. The catalog includes description of construction, sizes and condensed performance tables, and is fully illustrated with photos of units, system applications and sectional drawings. More than 80 pages are devoted to engineering and design data, including often-used formulas and tables and a new psychrometric chart for determining values of air properties in heating, cooling, humidifying and dehumidifying problems.

## Barometric Condensers

Ingersoll-Rand Company has issued a new 8-page bulletin (Form 9012) which covers both the disc-flow and the ejector-jet types of barometric condensers and explains the uses, advantages and operation of each. Several schematic diagrams illustrate how these vacuum-producing systems work and installation photographs show the condensers in various industries such as chemical, fertilizer, sugar and power plants.

## Centrifugal Pumps

"Self-Priming Centrifugal Pumps" is the title of a 20-page bulletin issued by Marlow Pumps which describes in simple language and with effective illustrations the fundamental physics of pumping and the evolution of self-priming centrifugal pumps. Diffuser-priming, characteristic of Marlow Pumps, is featured and information given regarding the installation and operation of self-priming centrifugal pumps.

## Vibration Control Unit

The Korfund Company has published a 4-page folder which describes its Type SL Universal Vibro-Isolator. This unit is said to absorb vibration in all directions and is claimed to furnish effective vibration control for a wide variety of applications, including punch presses, diesel engines, generators, panel boards, and ventilating and air-conditioning equipment. The bulletin is illustrated and contains data regarding the rated loads (200 to 12,000 lb), weights and dimensions.

## Apron and Pan Conveyors

Chain Belt Company have issued a 6-page folder (Bulletin No. 462) descriptive of Rex apron and pan feeders and conveyors for handling coal, coke, ore, cement, rock, chemicals, bulk parts and many other materials. The bulletin contains design details, cross-sections, capacity tables and specifications tabulated for quick comparison.

## Spreader Stoker

The Johnston & Jennings Company has issued a 4-page folder which illustrates and describes the new J & J Spreader Type Stoker. This unit features a rocking non-clogging coal feeder, a rotor with 3-bladed paddles and a small high-velocity fan which ensures distribution of fines in the furnace and air cooling of exposed parts. The units are built in four standard sizes, i.e., with rotors 16, 20, 24 and 32-in. wide.

## Motors

A new Protected-type Motor, designed for both drip-proof and open motor applications, is illustrated and described in a 4-page bulletin just published by the Crocker-Wheeler Division of Joshua Hendy Iron Works. Features of the motor include: centrifugal bearing seals, ALUCAST rotor, Vinyl Acetal protected windings, and internally shielded, partially enclosed frames and shields which prevent foreign matter entering the motor.

## Tachometers

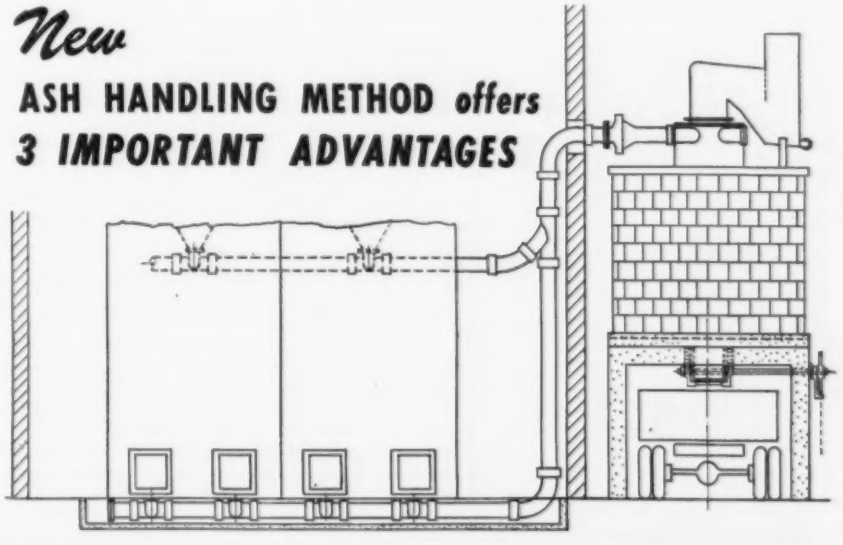
The Herman H. Sticht Company has just issued a new 4-page tachometer bulletin (No. 760) describing its Model J triple range hand tachometers of centrifugal type. Two new tachometers have been added to this line—one for all speeds between 100 and 12,000 rpm, the other for all speeds between 300 and 15,000 rpm.

## V-Belt Drives

Multiple V-Belt Texrope Drives are featured in a 12-page bulletin (B6051E) issued by Allis-Chalmers. Page 2 provides an index to a complete line of constant speed and adjustable speed Texrope drives and the information given concerning these is compactly arranged in the pages that follow. A sheave selector chart and a belt selection chart is also given.


*New*

**ASH HANDLING METHOD *offers* 3 IMPORTANT ADVANTAGES**



**In the Beaumont "Vac-Veyor" pneumatic ash handling system the exhauster, receiver, separator and air washer are combined as one unit. Operating advantages include: (1) All ash delivered into the silo, none into the air. (2) Ashes delivered practically dry, which minimizes the possibility of packing or freezing in the silo. (3) Continuous operation, with low steam consumption. What are your ash handling problems? Send today for literature.**

BEAUMONT BIRCH COMPANY

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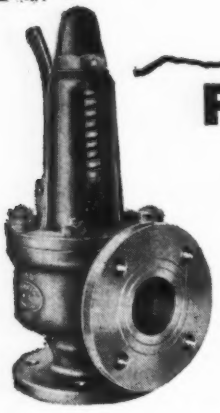
DESIGNERS • MANUFACTURERS • ERECTORS OF COAL AND ASH HANDLING SYSTEMS

Rx For prompt relief— from Relief Valve troubles— use FARRIS!

You'll find these FARRIS FEATURES unique!



FARRIS exposed spring Relief Valve No. 1100. Naval type, high capacity, with test lever. For liquid and backpressure service; pressures to 350 lbs. at 500° F. Sizes ½" to 4".

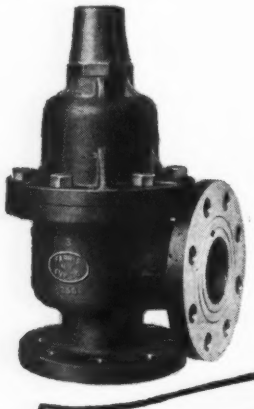
Another FARRIS Liquid Relief Valve, No. 1450. Enclosed spring, pressure-tight cap. Also test-lever and pop types. Screwed outlet available. For pressures to 600 lbs. Sizes 2" to 8"

**HIGH LIFT . . . accomplished by special FARRIS design, oversize springs, and "precision alignment." These features secure high-capacity discharge, necessary for the quick relief of over-pressure.**

**SPRINGS . . . protected from corrosive contact with discharged fluids. FARRIS springs are long, of carbon steel, low fibre stress, low pitch, and cadmium plated. Carefully calibrated to deliver accurate, dependable operation at the exact pressure set for relief action.**

**GUIDES . . . protected by FARRIS "precision alignment" from fouling; no sticking, or hanging due to distortion. Instant-action guarded!**

**SEATS AND DISCS . . . renewable — neither pressed nor rolled in. Special alloys and heavy construction fortify wear-resistance. FARRIS "Precision Alignment" produces tight precision reseating instantly after over-pressure is relieved, which minimizes the duration of relief action for economical operation.**



Drop us a line with full details of your Relief or Safety Valve problem. Our Engineering Department will gladly furnish recommendations for the proper valve — without obligation on your part!

*Write today for our Specifications Bulletin*

FARRIS ENGINEERING COMPANY

352 Commercial Ave., Palisades Park, N. J.

Farris

SAFETY and RELIEF VALVES


## Personals

**C. W. DeForest** has retired as vice president of the Columbia Engineering Corporation and its affiliate, the Cincinnati Gas & Electric Company.

**A. J. Tigges,** for a number of years associated with Jackson & Moreland, consulting engineers of Boston, recently joined The Air Preheater Corporation as a technical adviser. He is now located in New York.

**Sidney J. Robison,** recently retired from his position as chief engineer of the Universal Atlas Cement Company, has joined the staff of Western Precipitation Corporation. He will make his headquarters in Chicago and devote his time to special problems relating to the adaptation of electrical precipitators and multicyclones to the heavy industries.

**Roy R. Katterhenry** has been promoted to the position of executive assistant to the president and vice president of the Indianapolis Power & Light Company. His association with this company dates back to 1916, following graduation in electrical engineering from Tri-State College. His earlier assignments were in the construction department, later in the research department and then as purchasing agent.

**S. H. Mortensen,** chief electrical engineer of the Allis-Chalmers Mfg. Company has been chosen as the recipient of the 1944 Lamme Medal of the American Institute of Electrical Engineers, "in recognition of high achievements in the development of electrical apparatus and machinery."

**G. L. Elliott** has been appointed assistant to the president of Elliott Company. He was formerly general manager of that company's Springfield, Ohio, plant.

## Obituaries

**John R. Hagemann,** Manager of the Allis-Chalmers Mfg. Company's steam turbine department died on February 15. A native of Switzerland, Mr. Hagemann was a student of Dr. A. Stodola, the well-known turbine authority, at the Swiss Federal Polytechnic Institute. He came to the United States in 1927 in connection with the 160,000-kw Brown Boveri turbine-generator installed in this country at that time. Two years later he became associated with Allis-Chalmers, first as an assistant engineer, then as engineer in charge of steam turbine design, and in 1944 as manager of engineering in the steam turbine department.

**Arthur W. Patterson, Jr.,** vice president of The Engineer Company died at his home in Roselle, N. J., on March 5 following an illness of several months. He was seventy-three years old. A graduate of Stevens Institute of Technology with the class of 1892, Mr. Patterson spent a number of years with the Rand Drill Company, the Rumsey Pump Company

and Yale & Towne Mfg. Company before becoming associated with The Engineer Company in 1917 as vice president. He was a licensed professional engineer and a member of the A.S.M.E.

Immediate survivors are his widow, Mrs. Delarue H. Patterson and two sons, Lt. A. W. Patterson, 3rd, U.S.N.R. and Richard K. Patterson, of Columbus, O.

**Alfred C. Marshall,** former president of The Detroit Edison Company, died on February 9 following a brief illness. He was 72 years old.

After graduation from the University of Michigan in 1893, Mr. Marshall was employed by the Detroit Public Lighting Commission, and later was associated with the Railway System of that city. He subsequently became general manager of the Port Huron Light & Power Company, and in 1911 was made assistant to the president of the Eastern Michigan Edison Company. He was elected vice president of The Detroit Edison Company in 1913 and some years later took over the duties of general manager. Upon the death of Alex Dow, he was elected to the presidency of that company in which capacity he served until his retirement early last year. He was a fellow of the A.I.E.E. and a member of the A.S.C.E.

**Harvey M. Cushing,** well-known utility engineer, died recently in Buffalo at the age of 69. He had served for over 22 years as chief engineer of the Buffalo General Electric Company and supervised the electrical and mechanical engineering of the Huntley steam station, and later the Oswego station of the Niagara-Hudson System.

### H. STUART ACHESON

As we go to press word comes of the death of H. Stuart Acheson, Advertising Manager of COMBUSTION since it was founded, whose kindly personality will be recalled by many advertisers in the power equipment field. His death on March 13, at the age of seventy, followed a prolonged period of apparent slow recovery from an operation last fall. Despite this, he was more or less active until the last, having spent some time at his office the day before his death.

Educated at Columbia University and the University of Virginia, where his study of medicine was cut short by ill health, he spent some time ranching in the Southwest and then took up a newspaper career. This covered about twenty-five years, during which he was associated with several New York dailies as a reporter and subsequently as ship-news reporter, in which capacity he came to know many celebrities of the nineties and the early part of the present century. He later became operatic critic for one of these newspapers. During World War I he was a YMCA secretary in France. His connection with COMBUSTION dates back to 1919.

This wide and interesting experience was supplemented by extensive travels in Europe, the Orient and Central America.

Surviving are his wife, Maria Acheson, and a daughter, Mrs. Louis Jacques.

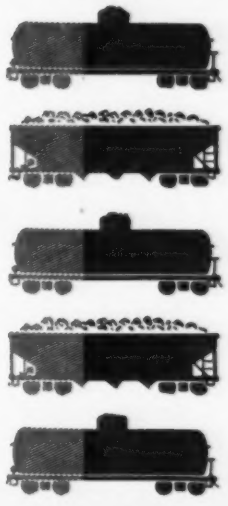

A Fuel Saving Method THAT IS

SIMPLE AND DEPENDABLE

Of all the plans, products and methods advocated as fuel-savers, Enco Streamline Baffles represent one of the simplest and most dependable means available.

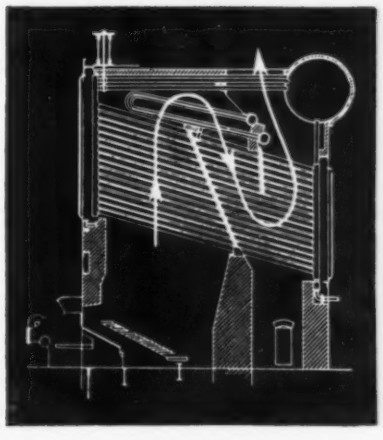
They are easily put to work because they are adaptable to any type of water-tube boiler—and the entire job can be turned over to this company.

Dependable because they are designed on sound engineering principles, backed by The Engineer Company's quarter-century of experience in this field. Baffles are individually designed to meet the requirements of each boiler. Installations are made by our mechanics whose skill in this work is unsurpassed.



*A Booklet Worth Having*

Details of these baffles, with descriptions of novel and ingenious constructions used in numerous types of boilers are available in this booklet. It is looked upon by many engineers as a reference book of real value. Your copy will be sent on request.



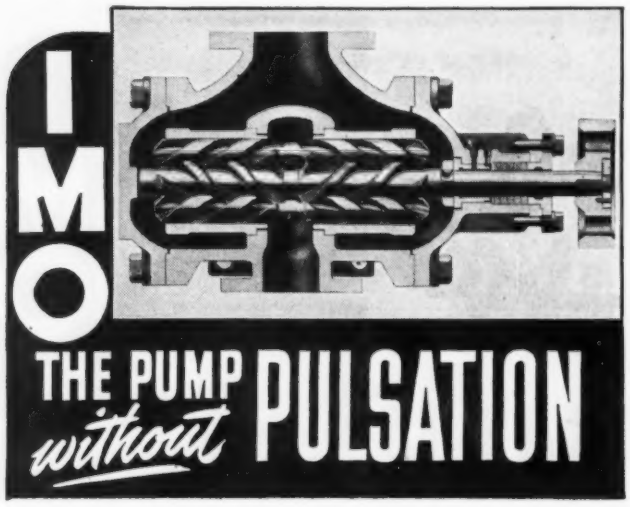
THE ENGINEER COMPANY

75 WEST STREET • NEW YORK 6, N. Y.

Canada: F. J. Raskin, Inc. • 370 Rachel E., Montreal, P. Q.

Enco Streamline Baffles

PRODUCED EXCLUSIVELY BY THE ENGINEER COMPANY




The steady, uniform flow produced by the continuous turning of the rotors in an IMO pump is ideal for oil burners, hydraulic and other service requiring an even, pulsation-free flow.

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PUMP DIVISION OF THE
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TRENTON 2, NEW JERSEY
I MOVE OIL

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